A global history of the road
Road construction, maintenance and use in Colombia, Argentina, French West Africa, and the Algerian Sahara, 1930-1970

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

King’s College London

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Declaration of originality

This thesis represents my own work. Where the work of others is mentioned, it is duly referenced and acknowledged as such.

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Copyright declaration

Abstract

This thesis presents the first historical study of twentieth-century road construction and maintenance on a global scale, and the first comparative study of roads outside Europe and the United States (US). From 1930 to 1970, the roads of Latin America, Africa and Asia experienced considerable length increase and, especially in the post-1945 period, the modification of their material characteristics. This transformation enabled the road structures and surfaces to withstand the rapidly increasing heavy traffic of a globalising and nationalising world. This thesis shows the importance of unpaved roads and freight transport, particularly in the developing world. It argues that many roads, especially in the developing world, were built as what were called low-cost roads. Built down to a price, rather than up to a standard, low-cost roads were designed to last half as long as high-quality roads. However, these roads were meant to be upgraded over time, therefore making maintenance and improvements essential to ensure future circulation. In fact, this thesis shows that maintenance and upgradeability were the crucial factors that allowed low-cost roads to bear the rapidly growing heavy traffic of the post-1945 period. This thesis therefore represents a shift away from the main themes of the existing historiography, which focus on private automobiles, motorways, tourism and leisure, and policy for road building.

This thesis makes the case for studying the materiality of twentieth-century roads. Road length alone did not guarantee the circulation of rising motor traffic: to talk holistically about roads is to talk about maintenance. Studying the physical properties of roads tells us not only about the link between maintenance, upgrades and the changing load-bearing capacity of roads, but also about the emergence of new road construction and maintenance tools and techniques that originated in the US and spread across the world. Indeed, adding to our understanding of the international influence of the US in the twentieth century, this thesis shows that American road-related standards, methods and equipment were the predominant model for the construction and maintenance of low-cost roads in the developing world, from the 1930s onwards, but especially during and after the Second World War. Professional networks of engineers, and their international exchanges, were crucial for the circulation and adaptation of this model to various environmental and traffic conditions across the world.

This thesis focuses on the cases of the Algerian Sahara, French West Africa, Argentina and Colombia – allowing for a comparison of varied extreme natural environments and complex

relationships between rail and road transport. Yet, this thesis also discusses the work of American engineers in the US and abroad in the context of the Second World War, and the approaches of British and French engineers in their empires. This thesis emphasises the period after the Second World War, when the particularly rapidly expanding traffic of the developing world accelerated road development and the modernisation of road construction and maintenance processes.

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Abbreviations from archival sources

ANOM - *Archives Nationales d'Outre-Mer* (Aix-en-Provence, France)

TP - Fonds Ministère des Colonies, Inspection Générale des Travaux Publics

BIB - Bibliothèque

NA - *National Archives* (London, United Kingdom)

DSIR, RRL – Department of Scientific and Industrial Research and related bodies; Road Research Laboratory and Successor

AGN - *Archivo General de la Nación* (Bogotá, Colombia)

AO-MOPT – Sección Archivos Oficiales, Fondo Ministerio de Obras Públicas y Transporte

RE - República, Fondo Ministerio de Obras Públicas

AR-BNMM - *Biblioteca Nacional Mariano Moreno* (Buenos Aires, Argentina)

ARCH-CEN - Departamento de Archivos, Fondo Centro de Estudios Nacionales, Subfondo Arturo Frondizi.

BL - *British Library* (London, United Kingdom)

IOR – India Office Records

World Bank Group Archives (Washington D.C., United States)

WB IBRD/IDA EXT - World Bank, International Bank for Reconstruction and Development, International Development Association, Records of Office of External Affairs

Abbreviations used in the text

AAC - Asociación Argentina de Carreteras

AASHO - American Association of Highway Officials

ACA - Automóvil Club Argentino

ACIC - Asociación Colombiana de Ingenieros Contratistas

ASTM - American Society for Testing Materials

BPR - Bureau of Public Roads (US)

BS - British Standard

CBR - California Bearing Ratio

CCCE - Caisse Centrale de Coopération Économique

CCFOM - Caisse Centrale de la France d'Outre-Mer

CEPAL - Comisión Económica Para América Latina

CFP - Compagnie Française des Pétroles (Algérie)

CSG - Compagnies Sahariennes du Génie

CSIDBPA - Chambre Syndicale des Importateurs et Distributeurs de Bitumen de Pétrole en Algérie

DoD - Department of Defense (US)

DNV - Dirección Nacional de Vialidad (Argentina)

FNC - Ferrocarriles Nacionales de Colombia

FIDES - Fonds d'Investissement pour le Développement Économique et Social des Territoires d'Outre-Mer

FOM - France d'Outre-Mer

FWA - French West Africa

GEDARS - Groupement des Entreprises pour l'Aménagement des Routes du Sahara

GEIPOT - Grupo Executivo de Integração da Política de Transportes

HRB - Highway Research Board (US)

IBRD - International Bank for Reconstruction and Development (World Bank Group)

ICE - Institution of Civil Engineers (London, Great Britain)

ICC - International Chamber of Commerce

IDA - International Development Association (World Bank Group)

IRF - International Road Federation

MIT - Massachusetts Institute of Technology

MOP - Ministerio de Obras Públicas de Colombia

OCRS - Organisation Commune des Régions Sahariennes

PIARC - Permanent International Association of Road Congresses

RRL - Road Research Laboratory (Great Britain)

SATPAN - Société Algérienne de Travaux Publics de l'Afrique du Nord

SCI - Sociedad Colombiana de Ingenieros

SENA - Servicio Nacional de Aprendizaje (Colombia)

SGE - Société Générale d'Entreprises

SOM - Subdivision d'Outillage Mécanique

TPG - Transportation Planning Group (Ministry of Public Works and Services, Argentina)

TRAPIL - Société des Transports Pétroliers par Pipeline

UN - United Nations

UNESCO - United Nations Educational, Scientific and Cultural Organization

USAID - United States Agency for International Development

UTAC - Union Technique de l'Automobile, du motocycle et du Cycle

YPF - Yacimientos Petrolíferos Fiscales (Argentina)

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Introduction

From 1930 to 1970, land transport experienced a revolution that conditioned and enabled globalisation. It was mainly related to the building, increased use and maintenance of roads. A rough estimate suggests that the number of motor vehicles in use in the world (excluding the Eastern Bloc) saw an increase of over 490 per cent from 1930 to 1971.[1] In contrast, the world's road network length increased by roughly 30 per cent from 1930 to 1967; although excluding Europe and the United States, this percentage rises to 53.7 per cent.[2] The world's railway mileage, on the other hand, decreased about 1 per cent from 1930 to 1965 (and about 6 per cent if the USSR is excluded).[3] As one would expect, rail traffic increased even so.[4] However, road transport generally increased much faster and, in particular, at a much more rapid pace than the road length itself. Rising traffic exerted increasing pressure on road networks, prompting the modification of road construction and maintenance processes.[5] This thesis explores this remarkable transformation in the carrying capacity of roads, focusing in particular on the case of the developing world.[6]

This thesis is the first historical study of this major change at a global scale, and the first comparative study of roads outside Europe and the United States.[7] This thesis argues that from 1930 to 1970, the roads of Latin America, Africa and Asia experienced considerable length increase and mostly major transformations of their material characteristics that allowed them to respond to the unprecedented transport demands of a globalising and nationalising world.[8] This thesis focuses on the cases of the Algerian Sahara, French West Africa, Argentina and Colombia – allowing for a comparison of varied extreme natural environments

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[1] Estimation based on figures on Annexe C.

[2] This estimation is based on Annexe A and includes only the countries/colonies for which data is available on the Annexe for both 1930 and 1967. It excludes, in particular, the USSR.

[3] *Directory of Railway Officials & Year Book 1966-1967* (London, 1967), 572-74. Estimation based on selected countries, see Annexe B.

[4] In fact, the 1954 *Oxford Economic Atlas* estimated that the world's railway freight traffic increased from 705,625 million ton-miles in 1938, to 1,317,500 million ton-miles in 1951. *Oxford Economic Atlas of the World* (London and Oxford, 1954), 109.

[5] Estimation based on figures on Annexe C.

[6] I will refer to Latin America, Africa and Asia as the developing world in order to avoid repetition. I will use the term developed world to refer to Western Europe and the United States.

[7] Unless explicitly mentioned, this thesis will not discuss road development in the Eastern Bloc.

[8] This thesis focuses on motorable roads, by which I understand roads that have been designed and built to accommodate motor vehicles. I will also make some references to tracks when relevant, i.e. routes used by motor vehicles but that were opened with minimal or no engineering intervention. I do not study motorways (or similar types of roads with limited access and designed for fast traffic), and unless explicitly noted I do not study roads within urban centres (streets).

and complex relationships between rail and road transport.[9] However, the approach of this thesis is much broader, as it also discusses the work of American engineers in the US and abroad in the context of the Second World War, and the work of British and French engineers in their empires. This thesis emphasises the period after the Second World War, when the particularly rapidly expanding traffic of the developing world accelerated road development and the modernisation of road construction and maintenance processes.[10]

Unlike most of the literature on the history of roads, this thesis focuses not on *why* roads were built, but on *how* roads were built and maintained. The work of engineers therefore acquires a central place in this analysis. These professional road engineers, coming from both Europe and the US as well as from Latin American countries, were educated in prestigious institutions (often American ones) and often belonged to the social elites of their countries.[11] Challenging the predominant historiographical focus in road history on passenger transport and limited-access highways, this thesis argues that the decisive phenomena of the period were rising freight traffic and ‘low-cost’ roads. A product of the prioritisation of network length over quality, low-cost roads were deliberately substandard and were only meant to last half as long as roads in developed countries. However, they were intended to be upgradeable: some of their characteristics were expected to be improved over time when funds became available and traffic demands made it absolutely necessary. Low-cost roads were the main type of road built in Latin America, Africa and Asia during this period. Although the US and Europe also built low-cost roads, these usually played secondary roles within the transport systems of developed countries, whereas they acquired a major role in the developing world.

These low-cost roads were mostly (but not necessarily) unpaved. And yet, they won a rising share of the transport of goods by land during the period, sometimes even surpassing railways. Roads also started being preferred to railways for the opening of new routes. This thesis suggests that this shift to roads was due to the low-cost road’s lower initial investment requirements, the promise of upgradeability, and the possibility roads offered of providing a service without optimal infrastructural conditions.

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[9] Although Chapter 1 studies entire road networks, the remaining chapters of this thesis focus on *main* road networks. For the French colonies this means the roads considered vital for the territory in particular, and the empire in general. For the case of Argentina and Colombia this means national road networks, as opposed to provincial/departmental and municipal.

[10] By modernisation, I refer to the adoption of the latest methods, equipment, and machines available for road design, construction, and maintenance.

[11] This thesis focuses on engineers working for public administrations, although engineers working for construction firms are also mentioned.

This thesis recognises, for the first time, not only the extraordinary and almost wholly unappreciated significance of the low-cost road, but also the influence of American road-related standards, techniques, and equipment in the evolution of the methods and tools associated with it – from the 1930s onwards, but especially during and after the Second World War. Even French and British engineers used and adapted American approaches to road building and maintenance at home and in the colonies, which shows that the exchange of engineering knowledge and practices often took place in ways that do not correspond to the commonly studied connections of metropole/colony and centre/periphery. Indeed, in order to understand the transformation of road construction and maintenance that the developing world experienced in this period it is necessary to take into account local and international engineering communities (including exchanges *within* the developing world). These communities adapted American approaches to local demands and conditions, creating variations around the predominant American model. Sometimes this generated solutions that did not emerge anywhere else, and the steps taken to accommodate animal-drawn traffic in some Asian countries illustrate this phenomenon.

Engineers working in the developing world were well aware of the need to adapt American techniques to local contexts. Although environmental conditions were indeed extreme in some cases, it was more the lack of knowledge about the environment, rather than the conditions themselves, which made road building particularly challenging. Therefore, even if engineers were open to using local knowledge, new knowledge about local materials and conditions had to be produced in order to accelerate construction and make road design more precise. When roads failed, it was usually not because of their neglect of the complexities of local environments and conditions, but because the novelty of the task of building motorable roads in certain contexts and at a rapid pace entailed certain risks.

Adaptation extended beyond technical measures, as both public and private organisations had to modify their road planning and management activities, a process that was particularly difficult for countries and colonies that were only just starting their modernisation of road development in the post-war period. The unexpectedly rapid growth in traffic during this period further complicated long-term planning.

Finally, in contrast to most histories of technology and mobility, maintenance occupies a central place in this thesis. To talk holistically about roads is to talk about maintenance: this issue was crucial for road engineers, even from the design stage. In the developing world, low-cost roads made maintenance even more crucial, as roads built to low standards required more attention simply to remain passable. It is therefore not surprising that technological innovation characterised not only road construction, but also maintenance. In addition, closely linked to improvement over time, maintenance was at the very centre of the notion of upgradeability. Thus, road maintenance in this context was often more about progressively creating something new, rather than returning the road to its original condition.

Roads and road freight have attracted much less attention than railways and automobiles in the historiography of the twentieth century, and this is especially the case in road development outside Europe and the US.[12] As the following review of the historiography shows, roads have generally remained in the background in accounts of globalisation, national histories, and even histories of transport and the automobile. This results from an overly narrow understanding of what the significant transport developments of the century were, which has focused on railways and the airplane, and from an emphasis by transport mobility historians on automobiles and consumers, at the expense of freight and the material aspects of road infrastructure. I further suggest that problematising roads by taking seriously their materiality offers important insights into how roads were made to respond to changing traffic demands, as well as the evolution of engineering and scientific knowledge, practices, and tools in the developing world in particular, and on a global level more generally. This introductory chapter finishes by laying out the structure of the thesis and briefly presenting the sources used.

Roads as both factors and results of globalisation and national development

Although there is no consensus about the definition of globalisation (or even whether it is a useful term for historical analysis), historians usually identify transport technologies as either factors, catalysers, or at least a necessary prerequisite of this phenomenon.[13] Historians of globalisation, in particular, highlight the role that certain transport and communications innovations had in the increasing volume and speed of the movement of people, ideas, capital, and goods that took place in this period. Transport innovations such as railways, steamships, containers, and airplanes usually sit alongside innovations in communications, such as telegraph, radio, satellites and the Internet, as fundamental elements in globalisation.

[12] In this thesis, I will use the term automobile to refer to specifically private cars. In the literature review I have retained the terms used by the authors.

[13] For a critique of the concept of globalisation and its usefulness for historical enquiries see F. Cooper, ‘What is the Concept of Globalization Good for? An African Historian’s Perspective’, in *African Affairs* 100 (2001), 189-213.

However, roads rarely, if ever, feature as causative factors in histories of twentieth-century globalisation. For instance, for the historian Bruce Mazlish, at the forefront of the New Global History initiative, the unprecedented levels of global interdependency and interconnectedness that characterised the world in the last three decades of the century, which compressed time and space, were prompted by sea vessels (and other unspecified transport methods), the telegraph, the radio, and satellites.[14] Indeed, transport technologies play only a limited role in his analyses, as unproblematic instruments that actors such as multinational corporations and inter-governmental organisations used in order to carry out their actions.[15] In fact, he attributes a much larger role to nuclear weapons, rockets, satellites, and computers as the technologies that have had the most important implications for the transcending of national boundaries.[16]

Even authors that explicitly seek to give ‘technology’ a major explanatory role in the history of globalisation tend to refer to the same transport and communications innovations and ignore roads. For example, in *Wiring Prometheus*, the editors Peter J. Lyth and Helmuth Trishler’s argue that over the last two centuries ‘a technology-driven process has steadily raised the level of connectedness between different parts of the world; and globalisation is the result’.[17] They identify two main waves of globalisation, and thus of technological advances: first, from 1840 to the start of the First World War, a wave propelled by the expansion of European communications and transport innovations (telephone, radio, telegraph, canals, railways, steamships and refrigeration); and second, from the 1970s and 1980 onwards, the rapid proliferation of ‘radical new technologies’ that accelerated and widened the flow of goods and information to the point that it has made of globalisation a synonym of capitalism, and in particular aerospace, air transport, satellites, lasers, microchips and fibre-optics.[18] Neither the introduction, nor any of the other chapters mentioned roads or

[14] The New Global History is an initiative born in the US in the late twentieth century led by Mazlish that seeks to trace the historical factors of globalisation. It attempts to distinguish itself from world history and from ‘weaker’ approaches of global history due to its planetary scope, its conception of the present as distinctive, and its specific aim of contributing to contemporary debates around globalisation. Bruce Mazlish, ‘Comparing Global History to World History’, in *The Journal of Interdisciplinary History*, 28 (1998), 391.
[15] See e.g. the role of faster transport and improved communications in the expansion of the scope of multinational corporations: Bruce Mazlish, *The New Global History* (New York, 2006), 36.
[16] Mazlish, *The New Global History*, 27-29.
[17] Peter J. Lyth, and Helmuth Trischler, *Wiring Prometheus: Globalisation, History and Technology* (Aarhus, 2004).
[18] Lyth, and Trischler, *Wiring Prometheus*, 12-13.

even road transport, focusing instead on railways and steamships, bicycles, textiles, the telephone, and computers.[19]

Roads have also been excluded from world histories that do not revolve around the historization of globalisation. For instance, in his environmental history of the world during the twentieth century, John McNeill dedicates significant space to the automobile, which he claims 'is a strong candidate for the title of most socially and environmentally consequential technology of the twentieth century', not only because of the air pollution it generated, but also due to its impact on territorial organisation.[20] However, besides mentioning the massive area that roads occupy worldwide (about one to two per cent of the land surface by the late twentieth century), he neglected the major transformation of ecosystems that such an expansion entailed, and pays no attention to the way in which road construction and maintenance were (and are) conditioned by climate, topography, soils, and geological formation.[21]

More recently, the *Cambridge World History* dedicated a whole chapter to transport and communications, in which Daniel Headrick argues that the age of transport and communications revolutions in which we live started two and a half centuries ago and resulted from two causes: the application of new machines and energy sources to transport methods, and what he calls the liberation of communication from the need to transport objects.[22] Headrick proceeds to make a chronological list of the most significant transport and communications innovations since 1750, which include animal- and human-drawn carts, steamships and railways, the telegraph, the telephone and central power stations (in relation to electricity), motor vehicles, airplanes, radio, satellites and computers. His essay is an exception in that he does highlight the importance of lorries for the movement of goods and points out the transformation that road networks experienced accordingly.[23] In fact, he states

[19] Other historians, such as Peter N. Stearns, Jürgen Osterhammel and Niels P. Peterson adopt similar narratives by highlighting two different waves of industrialisation (one in the nineteenth century and another in the twentieth century, especially after the Second World War) that reduced transport costs and increased the volume and speed capacities of the transport of goods and people. They do not make any explicit mention to roads playing a role in this process. Peter N. Stearns, *Globalization in World History* (London, 2009); Jürgen Osterhammel and Niels P. Peterson, *Globalization: A Short History* (Princeton, 2005).

[20] He also mentioned the importance of tractors for the evolution of agricultural production. John R. McNeill, *Something New under the Sun: An Environmental History of the Twentieth-Century World* (New York, 2000), 310.

[21] McNeill, *Something New under the Sun*, 311.

[22] Daniel R. Headrick, 'Transportation and Communication, 1750 to the Present', in John R. McNeill and Kenneth Pomeranz (eds.), *The Cambridge World History* (Cambridge, 2015), 401.

[23] Paul Josephson's contribution to this volume on twentieth-century technology also included a section on transport, in which he did put forward lorries and intermodal freight transport as important changes, but only explicitly mentioned road infrastructure in the case of the US Interstate Highway System, and

that roads became increasingly smoother and resistant to varied weather conditions, and that, although they were necessary for the spread of motor vehicles (and bicycles), their quality lagged behind the rise of the automobile until the first decades of the twentieth century when asphalt roads started to become 'standard'.[24] In the second half of the century, accelerated motorisation created congestion problems, to which governments in the West responded with the construction of limited-access highways, whereas 'non-Western countries with a similar proliferation of cars but less money to spend' were left with 'even more serious problems of congestion and pollution'.[25] The format of listing innovations means he does not note the persistence of unpaved roads, or the continued use of animal-drawn vehicles in countries such as India and Indonesia. Headrick's analysis illustrates some of the limitations of the historiography on roads. As the following section explains, the history of motorable roads has mostly revolved around the construction of motorways and the use of the automobile, leaving much of the world out and giving a misleading picture of the industrialised world as well.

The limited attention given to roads in twentieth-century world and globalisation history, if problematic, is not surprising. As the historian David Edgerton has pointed out, the history of technology of the twentieth century has until recently focused on the invention and innovation of only certain technologies whose significance has been more assumed than demonstrated.[26] This focus has had two consequences: first, we have an incomplete (or rather, misleading) account of twentieth-century invention and innovation, and second, we are missing a careful examination of technological use (not just users) and imitation. Roads and freight traffic present a good example of a vital technology whose development and role throughout the twentieth century have been systematically ignored, and its overall nature misunderstood. Moreover, once we start looking into the construction and maintenance of motorable roads, it quickly becomes evident that to talk about innovation in road development we also need to take seriously maintenance, adaptation, and use (see below). This perspective allows us to, not just include both the developed and the developing worlds in the history of roads, but also to deepen our understanding of their unequal and changing relationship, and of the way people, ideas, and things have moved around the world.

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this immense project of controlled-access highways can hardly be considered representative of road development around the world. Paul Josephson, 'The History of World Technology, 1750-Present', in McNeill and Pomeranz (eds.), *The Cambridge World History*, 136-163.

[24] Headrick, 'Transportation and Communication, 1750 to the Present', 412.

[25] Headrick, 'Transportation and Communication, 1750 to the Present', 414-16.

[26] David Edgerton, *The Shock of the Old, Technology and Global History since 1900, 2nd ed.* (London, 2019).

In contrast to the little attention given to roads in world and globalisation histories, roads have been awarded a larger place in histories of some nation-states, especially in Latin America. In this context, roads have been portrayed as playing significant roles in processes of nation-building in political and economic terms; a topic that I will explore in the following section.

Problematising roads

As Colin Divall and Ralf Roth note, compared to how much we know about cars, we know little about the rise and expansion of the modern road network, and in particular about its competition and interdependency with railway lines.[27] Although 'mobility' history seeks to move away from the study of the economic impact of transportation methods by producing an integrated vision of the movement of people and goods and including the perspective of the users, roads are still underrepresented.[28] Furthermore, there are significant gaps in what we know about roads. The following section presents a brief survey of the literature on roads in Europe and the US and in the developing world.

Modern networks in the US and Western Europe

The histories of road networks in Western Europe and the US during the twentieth century deal mostly with the emergence of modern limited-access highway networks (known as motorways in Britain, *autoroutes* in France, *autostrade* in Italy, and *Autobahnen* in Germany) in the United States and Western Europe. Indeed, the mileage they attained and the speed with which they were built make the American Interstate Highway System (41,000 miles of limited-access expressways) and the German Autobahn network (over 2,200 miles of concrete limited-access highways by 1942) ideal examples of the modernisation of roads.[29]

The aspect that has attracted the most attention has been the question of road policy, i.e. how the systems became politically, financially and administratively possible. Here, the work of Bruce Seely has been crucial for the American case.[30] Criticising interpretations he calls

[27] Colin Divall and Ralf Roth (eds.), *From Rail to Road and Back Again? A Century of Transport Competition and Interdependency* (Farnham, 2015), 1.

[28] John Armstrong, 'Transport History, 1945-95: The Rise of a Topic to Maturity', in *The Journal of Transport History*, 19 (1998), 103-21; Gijs Mom, 'What Kind of Transport History Did We Get? Half a Century of JTH and the Future of the Field', *The Journal of Transport History*, 24 (2003), 121-38.

[29] Bruce E. Seely, *Building the American Highway System: Engineers as Policy Makers* (Philadelphia, 1987), 3; Massimo Moraglio, 'The Highway Network in Italy and Germany Between the Wars: A Preliminary Comparative Study', in Gijs Mom and Laurent Tissot (eds.), *Road History: Planning, Building and Use* (Neuchâtel, 2007), 128.

[30] Seely, *Building the American Highway System*.

'deterministic', Seely rejects the idea that the American highway system was solely a result of the popularity of the automobile and its private and recreational use, and argues instead that in the early twentieth century road policy emphasised the enhancement of rural development and integration. In fact, not only associations of cyclists, but also farmers and even railway companies were crucial actors exerting pressure for the improvement of road surfaces.[31] The policy of extending road networks, not only from farms to markets, but also in-between cities, was also related to the emergence and rise of the lorry. The success of lorries during the First World War opened the path for the construction of new roads, while the damage caused by the rise in heavy traffic made evident the need to rebuild and adapt road construction techniques to these new vehicles. By the 1930s, when opinions on what sort of roads should be built started to diversify, lorry drivers were part of an expanding group of auto manufacturers and urban planners, among others, who were pushing to have a say in shaping road policy.[32] For Seely, however, the most decisive actors were the road engineers of the federal Bureau of Public Roads (BPR), since they shaped road development not only in their technical characteristics, but also in the political and financial aspects, in great part because they succeeded to establish a reputation as apolitical experts.[33] The actions of the BPR were therefore crucial for the approval in 1956 of the Interstate Highway System, which funded urban expressways as part of a network of trunk line highways.[34]

In the case of Europe, the state's promotion of tourism and automobile use has been accorded a major role in the emergence of modern road networks. The book *Road History, Planning, Building and Use* (2007) edited by Gijs Mom and Laurent Tissot is a good example of this approach. Moving away from interpretations that focused on the economic impact of transport systems, the authors of this book explore the roles of tourism, national style and identity, as well as centralisation and authoritarianism in the emergence of highway networks in Europe during the interwar years. An important argument in the book is that highway systems emerged in this period not as a result of the widespread use of the automobile (or any other motor vehicle) but rather in anticipation of demand. In both Italy and Germany, the construction of highways was seen as having an important propagandistic function since the

[31] As Seely notes, railway companies expected that better roads would increase their traffic. Seely, *Building the American Highway System*, 18.
[32] While lorry drivers were advocates of express highways, other groups, such as the urban planners, promoted urban freeways. Seely, *Building the American Highway System*, 227.
[33] Seely, *Building the American Highway System*, 3.
[34] Seely, *Building the American Highway System*, 226.

automobile and the highway corresponded to a vision of modernity and national pride that suited both Fascism and Nazism.[35]

The role of the private sector has also been highlighted in the emergence of European highways. In Italy, for example, most highways built during the Fascist period were designed, constructed, and managed by private groups or companies (such as Fiat), and most provided a link between large cities and tourist destinations.[36] Nevertheless, even in cases in which the state controlled and centralised road development, the lobby of the tourism industry and that of car manufacturers and other related industries (such as tyres, cement, amongst others) have been considered crucial motors of highway building.[37]

According to Mom, however, a level of centralised organisation is necessary for the emergence of a road *system* (in the way that Thomas Hughes understands them).[38] This means that, since in the early stages of a road network there is no central control over privately owned vehicles, it is only when the national authorities gain control of road networks through regulating mechanisms (such as traffic and tax laws, road signs and a traffic police) that we can talk about a road *system* with an identifiable builder who has 'enough executive power to implement his plans'.[39] For him, 'modern road building' has to take place at a national scale since regional governments do not have the power to render 'automobile mobility measurable and calculable', which is, according to Mom, a 'necessary condition for modern road building'.[40]

Although most authors studying European and American road networks have indeed adopted a national scale for their studies, the scholars attached to the 'Tensions of Europe' project are a notable exception. This initiative seeks to study the social tensions around the construction of the transnational technological networks that have been connecting and unifying Europe

[35] Moraglio, 'The Highway Network in Italy and Germany', 127.
[36] Moraglio, 'The Highway Network in Italy and Germany', 126.
[37] For the cases of Germany, Austria, and the Netherlands see Gijs Mom, 'Roads without Rails: European Highway-Network Building and the Desire for Long-Range Motorized Mobility', in *Technology and Culture*, 46 (2005), 745-72; Richard Vahrenkamp, 'Automobile Tourism and Nazi Propaganda: Constructing the Munich-Salzburg Autobahn, 1933-1939', in *The Journal of Transport History*, 27 (2006), 21-38; Thomas Zeller, '"National Character" and International Styles: Iconic Roads in Germany and the United States, 1930-1970', in Christof Mauch and Thomas Zeller (eds.), *The World Beyond the Windshield: Roads and Landscapes in the United States and Europe* (Ohio, 2008), 77-86; Bernd Kreuzer, 'National Road Networks in the 1930s: The Case of Austria's Roads', in Mom and Tissot (eds.), *Road History*, 99-116.
[38] Mom, 'Road without Rails', 760-761; Thomas Hughes, 'The Evolution of Technological Systems', in Wiebe Bijker, Thomas Hughes and Trevor J. Pinch (eds.), *The Social Construction of Technological Systems* (Cambridge, 2012), 51-83.
[39] Mom, 'Roads without Rails', 760-61.
[40] Mom, 'Roads without Rails', 760-61.

since the nineteenth and twentieth centuries. [41] The networks they study are mostly transport, communications, and electricity. Also borrowing from Hughes' large technological systems, these scholars concentrate on finding system builders and examining the negotiations that they had to undertake to materialise their visions of these networks.[42] With this objective, authors such as Johan Schot have highlighted the role of technical experts in shaping European road and electrical networks and transport policies before and after the Second World War.[43] Although this research consortium claims to be interested in the relationship between the material basis of the networks and the political developments that affected their shape, materiality actually occupies a small part of its work.[44] The Tensions of Europe initiative is mostly concerned with the genesis of Europe as a political and cultural entity.

Studies that explore the materiality of twentieth-century European and American road networks are, in fact, rare. First, the interactions of roads with the natural environment have remained in the background in most analyses, even when landscape transformations are put to the fore. In a volume edited by Thomas Zeller and Christof Mauch, the use of motor vehicles is portrayed as a new lens through which nature would be perceived: the windshield.[45] From the Alps to the Appalachians, many roads were designed to offer not only transportation but also impressive views that were meant to feed national pride for the beauty of the landscape and the technical achievements of the nation. This prompted the emergence of what Zeller called national 'styles': while the objectives and basic forms of highway networks were similar, their outlook and organisation were different.[46] This 'commodification of landscapes' did not go uncontested, and from the 1940s onwards a

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[41] See https://www.tensionsofeurope.eu/ (04/07/2019)
[42] Erik Van der Vleuten and Arne Kaijser, 'Networking Europe', in *History and Technology*, 21 (March 2005), 21-48; Johan Schot and Frank Schipper, 'Experts and European Transport Integration, 1945–1958', in *Journal of European Public Policy*, 18 (March 2011), 274-93.
[43] Johan Schot and Vincent Lagendijk, 'Technocratic Internationalism in the Interwar Years: Building Europe on Motorways and Electricity Networks', in *Journal of Modern European History*, 6 (September 2008), 196-217; Johan Schot and Frank Schipper, 'Experts and European Transport Integration, 1945–1958', in *Journal of European Public Policy*, 18 (March 2011), 274-93.
[44] For example, Frank Schipper examines the relation between the construction of a European road network with that of Europe's political integration in the twentieth century. However, he concentrates on studying the cross-national negotiations and debates around the formation of the road network, and dedicates only limited space to the material problems around road projects, especially the E-roads network. Yet, his analysis shows that the most complicated issues around the coordination of road traffic in Europe after the Second World War revolved around freight traffic. Frank Schipper, *Driving Europe: Building Europe on Roads in the Twentieth Century* (Amsterdam, 2008).
[45] Mauch and Zeller (eds.), *The World Beyond the Windshield*.
[46] Zeller, 'National Character'. It has also been noted that since the design of roads is often strongly influenced by political interests and cultural stereotypes, many projects can be highly controversial. See the classic example of Langdon Winner, 'Do Artifacts Have Politics?', in *Daedalus*, 109 (1980), 121-36; and more recently Anne Mitchell Whisnant, 'The Scenic is Political: Creating Natural and Cultural Landscapes Along America's Blue Ridge Parkway', in Mauch and Zeller (eds.), *The World Beyond the Windshield*, 59-78.

utilitarian vision of roads became dominant, as the cases of the US and Germany illustrate.[47] The flow of people and commodities was not to be interrupted or delayed as the efficiency and high speed of the circulation were seen as necessary conditions for economic growth.[48] Although the focus on landscapes presents roads as part of an environment and not as isolated elements, this perspective tells us more about the functional and aesthetic goals of roads than about the interactions between the natural environment and road design, construction and maintenance.

Second, road freight has attracted limited attention despite its impact on road development. Authors like Mom, Seely, Mark H. Rose and Paul F. Barrett have signalled the importance of lorry drivers in the road lobby in the US.[49] The drive towards modern road construction as a result of the increasing use of lorries from the First World War onwards (for military and commercial purposes) and the related damage caused to the roads has also been noted.[50] However, most histories of highway networks give a predominant place to the automobile, particularly in the context of urban road building.[51] And while there are many examples of sophisticated analyses about the production, distribution, and use of the automobile, we know much less about the specificities of lorries and other goods vehicles.[52] A deeper examination of the relationship between road development and freight transport opens valuable research avenues, as Richard Vahrenkamp's recognition of the role of road freight in the competition between roads and railways illustrate (see below).

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[47] Zeller, 'National Character', 84-85.
[48] Zeller, 'National Character', 84-85.
[49] See Mark H. Rose, Bruce Edsall Seely and Paul F. Barrett, *The Best Transportation System in the World: Railroads, Trucks, Airlines, and American Public Policy in the Twentieth Century* (Ohio, 2006); Gijs Mom, 'Constructing Multifunctional Networks: Road Building in the Netherlands, 1810-1980', in Mom, Tissot (eds.), *Road History*, 33-62.
[50] See e.g. Seely, *Building the American Highway System*; Louis Rodriquez, 'The Development of the Truck: A Constructivist History' (Lehigh Univ. D.Phil thesis, 1997). For the economic impact of road construction and the trucking industry in the interwar years see Alexander Field, 'Technological Change and US Productivity Growth in the Interwar Years', in T*he Journal of Economic History,* 66 (Mar. 2006), 203-36.
[51] For instance in the case of the U.S. see Clay Mcshane, *Down the Asphalt Path: The Automobile and the American City*, (New York, 1995); Owen D. Gutfreund, *Twentieth-Century Sprawl: Highways and the Reshaping of the American Landscape* (New York, 2004).
[52] For instance, Bernhard Rieger's *The People's Car* showed how the Volkswagen Beetle became a global icon and a global commodity after the Second World War, as it was produced and marketed within complex transnational networks, and acquired varied meanings depending on the distinctive economies and consumer cultures where it went. Bernhard Rieger, *The People's Car: A Global History of the Volkswagen Beetle* (Cambridge, 2013). For a more general reflection on the automobile's impact on the world's regimes of production and consumption see Bernhard Rieger, 'The Automobile', in McNeill and Pomeranz (eds.), *The Cambridge World History*, 467-89. For an example of the study of lorry design from an aesthetic point of view see Jean-François Grevet, '"Beau Comme un Camion" ou les Liaisons Entre Art et Industrie dans le Monde Automobile et Utilitaire des Temps Héroïques à l'Avènement du Design', in *Art & Industrie* (2013), 221-239.

Third, the study of the technical aspects of roads, advocated by Mom in 2003, still occupies a relatively small place compared to issues of planning, financing and automobile uses.[53] A significant exception is Seely's recent chapter in the book *From Rail to Road and Back Again?* (2015) in which he calls for the understanding of the American highway system as the product of technical developments, and not only organisational and financial ones. According to Seely, confronted with the challenge of building durable roads for an increasing number of ever heavier lorries from the 1920s onwards, American engineers adopted a range of slow, steady developments of 'mundane elements' which ultimately determined the specifications of the freeway system (and not the 'flashy, highly-publicized work labelled revolutionary').[54] However, Seely himself points out that, although new soil treatments and road pavements were important technical innovations, the widespread mechanisation of earth-moving equipment in the US after 1945 had such an impact in road construction, that topography stopped being a concern for American engineers since the movement of 'millions of cubic yards of earth' became economically viable.[55] Bulldozers, mixers and rollers, amongst other machines, made physically possible the very fast construction of the large American highway system. Francesca Russello Ammon also contributed to the history of the bulldozer during and after the Second World War by exploring its employment for building, clearing, and even fighting, and by tracing the use of bulldozers in the US in the context of post-war urban development projects and the first decade of the construction of the Interstate Highway System.[56] Nevertheless, such analyses remain largely isolated and authors who deal with road construction equipment are mainly enthusiasts.[57]

There are other material aspects of road construction and maintenance that have attracted only limited attention. Irving B. Holley contributed to the history of American road construction by telling the story of small contractor firms in the early stages of road construction from

[53] Mom, 'What Kind of Transport History Did We Get?'.
[54] Bruce Seely, 'Inventing the American Road: Innovations Shaping the American Freeway, in Divall and Roth (eds.), *From Rail to Road and Back Again?*, 242-43, 264.
[55] Seely, 'Inventing the American Road', 244.
[56] Along similar lines, Ralph Harrington studied the use of bulldozers in post-war Britain, focusing on how the machine became a symbol of modernity from a positive and then a negative point of view (in terms of environmental destruction). Ralph Harrington, 'Landscape with Bulldozer: Machines, Modernity and Environment in Post-war Britain', in Jon Agar and Jacob Ward (eds.), *Histories of Technology, the Environment and Modern Britain* (London, 2018), 41-61; Francesca Russello Ammon, *Bulldozer: Demotion and Clearance of the Postwar Landscape* (New Haven, 2016).
[57] See Francis Pierre and Heinz-Herbert Cohrs, *The History of Road Building Equipment*, The Classic Construction Series. Road Building History (Wadhurst, 1998); Heinz-Herbert Cohrs, *500 Years of Earthmoving*, The Classic Construction Series (Wadhurst, 1997). For an important exception see William Haycraft, *Yellow Steel: The Story of the Earthmoving Equipment Industry* (Illinois, 1999). There are also a few books focusing on a single manufacturer or product (mostly agricultural equipment) but they have little about the earthmoving equipment industry or about the use of the machines, see e.g. Reynold M. Wik, *Benjamin Holt and Caterpillar: Tracks and Combines* (St. Joseph, 1984).

1895 to 1925. He contends that small-scale operators were the ones that undertook most road construction during this period and that, by the mid-1920s, the infrastructure to build the large American system was already in place.[58] The elements that contributed to this success were: the adoption of machinery previously used for agriculture and railway building (which made road projects economically feasible despite the increasing costs of labour), the creation of varied mechanisms to circulate engineering knowledge that did not depend on professional engineers and their networks (since most operations during the period were not led by engineers), and the growing experience of small and medium contractors. The experience of both workers and managers was essential to minimise risks in both technical and managerial terms.[59] Nonetheless, generally speaking, the evolution of maintenance and construction practices, techniques and machinery over the course of the twentieth century are still largely unexplored.

Finally, another important issue that has only started to attract attention recently is the relationship between rail and road infrastructure. The volume edited by Divall and Roth sets out to examine this issue the context of Europe and the US from the early twentieth century onwards, although it focuses mostly on the interwar period and the twenty first century.[60] They note that the idea of two separate railway and automobile 'ages' is misleading, as railways were very unevenly distributed around the world and trains continued to be used despite the major shift from rail to road that took place over the course of the twentieth century. In fact, in absolute terms rail transport increased in some countries.[61] The editors also suggest that roads responded to limitations of railway transport such as cargo freight and door-to-door services.[62] In particular, in the case of Britain during the interwar years (the case discussed in most depth in the volume), Divall and Roy Edwards argue that these limitations were partly the result of a tariff policy that was meant to place railways as *the* national transport method in charge of evenly spreading the economic benefits of transport, and partly the consequence of the short-sightedness of the Ministry of Transport which was slow to recognise the benefits of combining road and rail haulage activities.[63] Railway companies

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[58] I. B. Holley, *The Highway Revolution, 1895-1925: How the United States Got out of the Mud* (Durham, 2008), 75, 163.
[59] In fact, according to Holley, estimating costs was the main challenge for the contractors since the inexperienced were not familiar with the problems that could arise from the construction of roads without any soil studies and in places far from water and energy sources. Record keeping was also an important ability contractors had to learn in order to manage and get the necessary capital to work on larger projects, Holley, *The Highway Revolution,* 78.
[60] Divall and Roth (eds.), *From Rail to Road and Back Again?*, 1.
[61] Divall and Roth (eds.), *From Rail to Road and Back Again?*, 24-25.
[62] Divall and Roth (eds.), *From Rail to Road and Back Again?*, 32.
[63] This policy regulated the price of the service according not to transport cost but to the value of the cargo, which had the objective of cross-subsidising low value services. Roy Edwards, 'Shaping British

struggled to compete against road haulers who had the liberty to set their own prices, choose the most profitable routes, use increasingly larger and heavier lorries, and benefit from rising public road investment. In contrast, even after nationalisation, the railways seem to have suffered from a comparative shortage of investment, a situation that was aggravated by the restricted loading gauge of the British rail infrastructure at a time in which 40-foot sea containers were becoming popular in the national and international transport market.[64] Although these are important advances, much remains to be studied about the relationship between roads and railways.

In particular, a global vision of this issue is much needed. Why did road transport grow so rapidly outside the Eastern Bloc whereas railways appear to have dominated within it? Although there appears to be no studies that tackle this question at this scope, Richard Vahrenkamp shows, building on Lewis Siegelbaum's work, that the predominance of railways in the Soviet Union did not result from an ideological bias against road transport.[65] Siegelbaum noted that after a slow start to road development with propagandistic objectives in the 1920s and 1930s, the Soviet Union turned towards roads in a more decisive way in the mid- to late-1950s with the mechanisation of road construction, the corresponding professionalisation of road-building crews, and the reorganisation of labour for road construction and upkeep.[66] According to Vahrenkamp, in the post-war period similar arguments about the modernity and advantages of road transport circulated in both the West and the Eastern Bloc.[67] However, road development faced many obstacles in the communist world. First, economic shortages made investments in a new form of transport infrastructure less appealing (especially since the railway infrastructure was for the most part already there), which meant that road networks remained poor in terms of coverage and conditions.[68] Second, motor vehicle production did not take off, the car lobby was weak, and the lack of

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Freight Transport in the Interwar Period: Failure of Foresight or Administration, 1919-34?', in Divall and Roth (eds.), *From Rail to Road and Back Again?*, 77-90; Colin Divall, 'Conceiving Distribution in the UK: the (London and) North Eastern Railway's Discursive Response to Road Haulage, 1921-39', in Divall and Roth (eds.), *From Rail to Road and Back Again?*, 91-108.

[64] Terry Gourvish, 'The Sea Container Revolution and Road-Rail Competition in Britain: A Preliminary Assessment of Freightliner', in Divall and Roth (eds.), *From Rail to Road and Back Again?*, 133-152.

[65] Lewis Siegelbaum, 'Roadlessness and the "Path to Communism": Building Roads and Highways in Stalinist Russia', in *The Journal of Transport History*, 29 (September 1, 2008), 277-94.

[66] Siegelbaum, 'Roadlessness and the "Path to Communism"', 277-94.

[67] According to him, in the German Democratic Republic the authorities considered the railways unable to meet modern transport requirements, a position that was more radical than in West Germany, where measures were taken to protect railways from the competition of lorry traffic. Despite this, the government invested in the modernisation of the railway. Richard Vahrenkamp, 'Coping with Shortage and Chaos: Truck Cargo Transport in the Eastern Bloc, 1950–1980', in *Icon* 21 (2015), 140.

[68] An exception was Bulgaria, where by the 1950s lorry freight traffic had a share of 80 per cent because of the lack of railway links. Vahrenkamp, 'Coping with Shortage and Chaos', 127.

standardisation in lorry production across the Bloc made the repair and maintenance of the fleet very difficult. These factors, added to the preference for the heavy industry and the limitations of the production of consumer goods, made for a comparatively low demand for road construction and maintenance.[69] In contrast, by the interwar period Western countries had already begun to develop new distribution channels and with them the proliferation of new packaged manufactured goods, department stores, and retail chains, which in turn changed the needs of warehousing centres and networked distribution to the benefit of lorry transport.[70] The development of mass consumption societies increased the demand for smaller, but more urgent deliveries (including fresh food) – a task the railway was ill-prepared to perform. While lorry traffic was becoming faster and cheaper and road construction was relatively less capital-intensive, the railway handling points were getting congested and their capacity was not easy to increase. Therefore, for Vahrenkamp, lorries were better suited than railways for the functioning of mass consumption societies, with the exception of bulk transport.[71]

Roads in developing countries and colonies

The history of twentieth-century roads in the developing world is difficult to trace because there have been few attempts to draw general conclusions at the scale of countries, empires or regions. Generally speaking, the subject of roads occupies a chapter or only a couple of pages in general histories, which are much more inclined to discuss the history of railways than any other transportation method. However, over the last ten years or so, a rising interest for roads in developing countries/colonies is visible, for instance, in the *Journal of Transport History*.[72]

As with developed countries, the relation between roads and the state (both national and colonial) has also been one of the major concerns in the literature about road networks in the developing world. Going back to the eighteenth and nineteenth centuries, the emergence of colonial road networks has been interpreted as playing an important part in the consolidation of empire. As road networks grew over the twentieth century, they not only had administrative and military functions, but also the responsibility of allowing the export of agricultural

[69] Vahrenkamp, 'Coping with Shortage and Chaos', 140-141.
[70] Vahrenkamp, 'Coping with Shortage and Chaos', 1-16.
[71] Vahrenkamp, 'Coping with Shortage and Chaos', 1-16.
[72] From 2000 until 2018, out of twenty-six articles dealing with the subject of roads or road transport, nine were studies on countries outside the US and Europe (China, Mexico, Latin America, Africa, the Dutch East Indies, Yugoslavia and Russia).

commodities at a competitive price while opening markets for metropolitan manufactures.[73] According to Libbie Freed, writing about French Equatorial Africa and Cameroon from 1890 to 1960, these political, commercial and administrative functions of road networks made them, in the eyes of the colonizers, crucial instruments for ensuring control over the conquered land, its resources and its inhabitants.[74] In fact, road development was a way of imposing direct imperial control over the local people given the importance of forced labour. In the Gold Coast, Portuguese Guinea, French West Africa and the Dutch East Indies, for instance, road construction and maintenance relied extensively (or sometimes entirely) on unpaid labour.[75] This was not unusual in the construction of public works in the colonies.[76] However, as forced labour gradually disappeared over the course of the twentieth century, traffic regulations and tax collection (related to and facilitated by roads) contributed to the control and 'disciplining' of the population.[77]

Various authors have suggested that the local populations contributed to road construction and maintenance not only with unskilled labour, but also with their knowledge and practices. Existing indigenous paths and engineering skills were often used as guidance, or were at least acknowledged by colonisers. For instance, in the hills of the North-Eastern Indian frontier,

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[73] For the case of India for example see David Arnold, *The New Cambridge History of India III: Science, Technology and Medicine in Colonial India* (Cambridge, 2000), 109; Lipokmar Dzuvichu, 'Roads and the Raj: The Politics of Road Building in Colonial Naga Hills, 1860s-1910s', in *The Indian Economic and Social History Review*, 50 (2013), 473.

[74] Libbie Freed, 'Networks of (Colonial) Power: Roads in French Central Africa after World War I', in *History and Technology: An International Journal*, 26 (2010), 203; Libbie Freed, 'Conduits of Culture and Control: Roads, States, and Users in French Central Africa, 1890-1960' (Univ. of Wisconsin-Madison D. Phil. Thesis 2006).

[75] See Freed, 'Networks of (Colonial) Power'; Marie-Lousie Ten Horn-Van Nispen, and Wim Ravesteijn, 'The Road to an Empire: Organisation and Technology of Road Construction in the Dutch East Indies, 1800-1940', in *The Journal of Transport History*, 30 (2009), 40-57; Jan-Bart Gewald, Sabine Luning, and Klaas van Walraven (eds.), *The Speed of Change: Motor Vehicles and People in Africa, 1890-2000* (Leiden, 2009); Kwabena Opare Akurang-Parry, 'Colonial Forced Labor Policies for Road-Building in Southern Ghana and International Anti-Forced Labor Pressures, 1900-1940', in *African Economic History* (2000), 1-25.

[76] See for example Martin Klein, *Slavery and Colonial Rule in French West Africa* (Cambridge, 1998).

[77] It is worth stating that the formal abolition of forced labour did not necessarily imply the radical disappearance of some its practices, especially in relation to public works, and road maintenance in particular. See e.g. F. Cooper, *Decolonization and African Society: The Labour Question in French and British Africa* (Cambridge, 1996); Víctor Fernández Soriano, '"Travail et Progrès" : Obligatory "Educational" Labour in the Belgian Congo, 1933-60', in *Journal of Contemporary History*, 53 (2018), 292-314; Alexander Keese, 'Slow Abolition within the Colonial Mind: British and French Debates about "Vagrancy", "African Laziness", and Forced Labour in West Central and South Central Africa, 1945-1965', in *International Review of Social History*, 59 (2014), 377-407; Zachary K. Guthrie, 'Forced Volunteers: The Complexities of Coercion in Central Mozambique, 1942-1961', in *International Journal of African Historical Studies*, 49 (2016), 195-212; Sarah Kunkel, 'Forced Labour, Roads, and Chiefs: The Implementation of the ILO Forced Labour Convention in the Gold Coast', in *International Review of Social History*, 63 (Dec. 2018), 449-76. In addition, manual labour did not disappear despite the widespread mechanisation of road works, see Chapter 2 and Dzuvichu, 'Roads and the Raj', 474; Jan-Bart Gewald, Sabine Luning and Klaas van Walraven, 'Introduction', in Gewald, Luning and van Walraven (eds.), *The Speed of Change*, 5.

indigenous roads were built with the easiest gradients possible and British officials occasionally praised the multiple 'scientific' mechanisms adopted by natives to avoid damage from the rain.[78] In addition, local practices also shaped roads regardless of the acknowledgment of colonisers even if it was, as Freed puts it, filtered 'through the lens of forced labour'.[79] It is, however, very difficult to measure or even describe the indigenous input in road construction in most cases. Notwithstanding, many authors have noted that it would be mistaken to consider that there was no native influence in colonial road construction, or that there were no local initiatives to build and maintain roads. In Nigeria, for example, the Native Administrations (village communities under the leadership of their chiefs who in turn were under the control of the District Officers and the Public Works Department) maintained almost three times as many kilometres of roads as the Public Works Department itself (24,325 km against 9,454 km in 1938).[80] Moreover, in some regions the Native Administrations – and not the Public Works Department – maintained the few motorable roads.[81]

Another way in which native agency has been emphasized is through the use of commercial vehicles. Users, drivers, repairers, sellers and often owners of vehicles, the local population was actively involved in the meeting of its own transport needs.[82] Jennifer Hart's book on mobility in Ghana in the twentieth century is a good example of this type of contribution.[83] She shows how in a colonial context Africans embraced imported motor vehicles, transformed them, and used them to serve their own purposes. Beyond the appropriation of vehicles, Hart argues that the rise of motor transport in Ghana resulted in a uniquely African culture and practices of automobility that provided a new language for African aspirations. This was considered a threat by both the colonial and the postcolonial states, which attempted to regulate and control traffic in order to consolidate their own power. Hart's analysis also highlights that in Africa automobility was more often about commercial motor transport than

[78] R. G. Woodthorpe, 'Notes on the Wild Tribes Inhabiting the So-Called Naga Hills, on Our North-East Frontier of India, Part I', in *The Journal of the Anthropological Institute of Great Britain and Ireland*, XI (1882), quoted in Dzuvichu, 'Roads and the Raj', 484.
[79] Freed, 'Networks of (Colonial) Power', 212.
[80] O. N. Njoku, 'Development of Roads and Road Transport in Southeastern Nigeria, 1903-1939', in *Journal of African Studies*, 5 (1978), 474.
[81] Njoku, 'Development of Roads and Road Transport', 474.
[82] It was often the case that Europeans drove comfortable automobiles while the natives drove and used larger vehicles that were adapted to both passenger and goods transport, although with minimum comfort. See Njoku, 'Development of Roads and Road Transport'; Philip J. Havik, 'Motor Cars and Modernity: Pining for Progress in Portuguese Guinea, 1915-1945', in Gewald, Luning and van Walraven (eds.), *The Speed of Change*, 71.
[83] Jennifer Hart, *Ghana on the Go: African Mobility in the Age of Motor Transportation* (Bloomington, 2016).

about private cars, and was shaped by poverty, weak infrastructure development and underfunded public services.[84] Motor vehicle ownership in Africa was therefore, according to Hart, not a question of personal autonomy and freedom (as it was for Europe and the US), but mostly of commercial use and entrepreneurship.[85]

Related to this focus on native agency is the argument that roads did not only serve the purposes of the state, but also fostered indigenous activities which were considered threats by the authorities. For instance, in French central Africa the recruitment of forced labour, and particularly the resettlement of communities alongside the roads for the ongoing maintenance of the surfaces, generated resistance and severe tensions between the administrators and the local populations.[86] Moreover, local political allegiances and inter-relations did not disappear under the colonial regime. The distribution of road work was often manipulated by communities with influence over other groups, which meant that road labour would often be in the hands of troublemakers or simply the powerless and poor.[87] In addition, as more and more administrators used automobiles, the spaces away from the motorable roads offered a shelter from the colonial vigilance and supplied 'important spaces in which to conduct economic and social life'.[88]

The issue of who controlled road access has attracted some attention, revealing the major role that social, political, and economic inequalities have played in road development and circulation. Recently, Simón Uribe showed that the construction and use of a road near the southern frontier of Colombia (stretching from the city of Pasto to the port of Puerto Asís) had a history characterised by conflict and violence. After forcing indigenous communities to work on the construction and maintenance of this road, in the 1910s Capuchin Missionaries condemned indigenous practices on the roads for being damaging to the surfaces.[89] In the second half of the twentieth century, road access was still a source of conflict in Colombia, as traffic on several rural roads far from urban centres could be interrupted not only by army

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84 Hart, *Ghana on the Go*, 11.
85 Hart also points out that from the 1920s Africans organised themselves to build and maintain their own roads. However, she does not study this phenomenon despite the fact that the appropriation of the road infrastructure (and not just motor vehicle use) is an important part of her argument. Hart, *Ghana on the Go*.
86 Freed calls French central Africa the former French Equatorial Africa and Cameroon. Freed, 'Networks of (Colonial) Power', 216.
87 Freed, 'Networks of (Colonial) Power', 216.
88 Freed, 'Networks of (Colonial) Power', 216.
89 These activities included the exploitation and dragging of wood with the help of oxen. At the time, indigenous communities were also dispossessed of their lands in order to found the city of Sucre, which was expected to facilitate the settlement of more inhabitants along the road. Simón Uribe, 'State and Frontier: Historical Ethnography of a Road in the Putumayo Region of Colombia' (London School of Economics and Political Science D. Phil. thesis, 2013), 146, 159.

checkpoints or the police, but also by illegal armed forces (guerrillas and paramilitaries), which could demand the payment of tolls as high as they considered appropriate.[90]

If the history of roads in developed countries is a story of gradual modernisation, in colonial contexts road use has been characterised as having contradictory effects. In a recent article, David Arnold discussed the issue of Indian urban traffic and modernity in the early twentieth century. While the increasing presence of motor vehicles and their use by both Europeans and Indians created a 'problem of traffic' that could be considered typical of a modern city, the ways the local populations used the streets were different from those of modern European urbanites. 'Pre-modern' methods of transportation were still in use and early attempts to modernise the people's habits as pedestrians, bicycle riders and motor vehicle drivers encountered resistance.[91] Given that these conflicts intensified over the course of the century, for Arnold Indian streets both symbolically and practically represented a 'fractured, disputed modernity'.[92] However, Arnold did not study the circulation of 'pre-modern' vehicles outside urban centres, nor the effects they had on road construction and maintenance, and by insisting on the contrast between 'old' and 'modern', he misses the story of the evolution of these non-motorised vehicles (e.g. bullock carts acquired rubber tyres over the course of the twentieth century), as well as the emergence of other types of vehicles that were invented in 'modern times', such as auto-rickshaws.[93]

In postcolonial contexts, roads have been generally related to national economic development, while mass motorisation has been associated with a process of democratisation and citizenship (as in developed countries). In Latin America, for instance, the scope and the speed of the construction of railways and roads have been considered key factors of economic growth through the reduction of transport costs, which in turn fostered exports of raw materials, imports of goods, activities directly or indirectly related to foreign investment, and a 'rising share of modern manufacturing output'.[94] William Summerhill contends that by the

[90] Uribe, 'State and Frontier'.
[91] David Arnold, 'The Problem of Traffic: The Street-Life of Modernity in Late-Colonial India', in *Modern Asian Studies*, 46 (2012), 119-41.
[92] Arnold, 'The Problem of Traffic', 120.
[93] See Rob Gallagher, *The Rickshaws of Bangladesh* (Dhaka, 1992); Yann Philippe Tastevin, 'Autorickshaw: Émergence et Recompositions D'une Filière Entre l'Inde, l'Égypte et Le Congo' (unpublished Doctorat d'Ethnologie, Université de Paris Ouest Nanterre la Défense, 2012); David Edgerton, *The Shock of the Old*; David Arnold and Erich Dewald, 'Cycles of Empowerment? The Bicycle and Everyday Technology in Colonial India and Vietnam', in *Comparative Studies in Society and History*, 53 (2011), 971-96.
[94] William R. Summerhill, 'The Development of Infrastructure', in Victor Bulmer-Thomas, John Coatsworth, and Roberto Cortes-Conde (eds.), *The Cambridge Economic History of Latin America* (Cambridge, 2006), 294.

1930s roads replaced railways as the central component of infrastructure expansion policy.[95] Brazil is a good example of how discourses from the state and private American enterprises (such as Ford, General Motors or Firestone) presented the automobile as a consumer good essential to a modern lifestyle and as a simple formula to bring progress and unity to the nation.[96] The manufacture of motor vehicles in Brazil from the second half of the 1950s was also meant to create a worker class with 'discipline' and 'no racial bias', two aspects that Brazilians thought characterised American autoworkers.[97] Moreover, due to the popularisation of car ownership, it has also been suggested that automobiles were vessels of democracy and that, overall, the automobile became a symbol of the quest of a modern, developed and democratic nation.[98]

However, focusing on the discourses of democracy and nation-building and on the data on economic growth can mask many inequalities and socio-political conflicts that have characterised road construction and maintenance in developing countries. Michael Bess contends that in Mexico during the 1940s and early 1950s, although road building was an essential element of the economic modernisation of the country, behind the rhetoric of regional economic integration and development the government prioritised the road projects that would facilitate access to Mexico's production centres and ports, neglecting the connections in areas less significant for international trade.[99] Although the interests of local agents sometimes conflicted with those of the state, cooperation between them was possible because they attributed sufficiently similar functions to road construction.[100] In this way, Bess concludes that road construction can be understood as a metaphor for the formation of modern Mexico, 'revealing it to be the sum of fragmented, but often overlapping social and economic interests'.[101]

Other kinds of inequalities are related to race and socio-economic marginalisation. In the case of South Africa, road infrastructure was designed to serve the state's mechanisms of surveillance and control over African movement during the apartheid period (1948-1994). As Mark Lamont and Rebekah Lee point out, roads were planned to facilitate the commute of African labourers from the townships into the city, as well as the access of state security

[95] Summerhill, 'The Development of Infrastructure', 326.
[96] Joel Wolfe, *Autos and Progress : The Brazilian Search for Modernity* (New York, Oxford, 2010), 9.
[97] Wolfe, *Autos and Progress*, 9.
[98] Wolfe, *Autos and Progress*, 12.
[99] Michael Bess, 'Routes of Conflict: Building Roads and Shaping the Nation in Mexico, 1941-1952', in *The Journal of Transport History*, 35 (2014), 78, 90. See also Michael Bess, *Routes of Compromise: Building Roads and Shaping the Nation in Mexico, 1917-1952* (Lincoln, 2017).
[100] Bess, 'Routes of Conflict', 82-89.
[101] Bess, 'Routes of Conflict', 94.

forces in case of mobilisation or social unrest.[102] However, in residential areas there was very little consideration for the need of public transport (mostly used by Africans) or the needs of pedestrians, making difficult the mobility of the African working class.[103] Despite recent efforts to improve this situation in post-Apartheid South Africa, many problems remain unresolved, such as the difficult connection between the expanding townships.[104]

There is another important element about the history of roads that is frequently mentioned in the literature: the influence of the US. For instance, it has been noted that even in certain British colonies imports of Ford, General Motors and Dodge lorries consistently surpassed the imports of Austin and Bedford lorries, while in Brazil Ford passed from assembling to manufacturing lorries in 1957.[105] In response to British attempts to limit American sales by prohibiting left-hand drive vehicles in their colonies American companies started making vehicles according to the British specifications.[106] Other important American companies related to motor transport also permeated the world's market, such as Firestone and Caterpillar.[107] Many engineers around the world received their professional education in the US and closely followed American engineering conferences, publications and public works construction (as did the ones who did not study in American institutions).[108] This could influence not only road construction practices, but also the institutional organisation of the road and transport public sector, as Valeria Gruschetsky argued for the case of the Argentinian road authorities.[109]

The evolution of road technical specifications has occupied some space in the literature. The development of motor traffic particularly after the First World War, and the different road surfaces used to respond to their needs has been noted by authors such as Philip Havik, Marie-Louise ten Horn-van Nispen and Wim Ravesteijn for the cases of Portuguese Guinea and the Dutch East Indies, respectively.[110] Ten Horn-van Nispen and Ravesteijn linked motorised

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[102] Mark Lamont and Rebekah Lee, 'Arrive Alive: Road Safety in Kenya and South Africa', in *Technology and Culture*, 56 (2015), 474.
[103] Lamont and Lee, 'Arrive Alive', 475.
[104] Lamont and Lee, 'Arrive Alive', 483.
[105] Simon Heap, 'The Development of Motor Transport in the Gold Coast, 1900-39', in *The Journal of Transport History*, 11 (1990), 19-37; Richard Downes, 'Autos over Rails: How US Business Supplanted the British in Brazil, 1910-28', in *Journal of Latin American Studies*, 24 (1992), 551-83.
[106] See for instance Heap, 'The Development of Motor Transport in the Gold Coast', 25.
[107] Downes, 'Autos Over Rails'.
[108] Thomas Campanella, '"The Civilising Road": American Influence on the Development of Highways and Motoring in China, 1900-1949', in *The Journal of Transport History,* 26 (March 1, 2005), 78-98; Downes, 'Autos over Rails'.
[109] See also Chapter 4. Valeria Gruschetsky, 'Saberes sin Fronteras. La Vialidad Norteamericana como Modelo de la Dirección Nacional de Vialidad, 1920-1940', in Mariano Ben Plotkin and Eduardo A. Zimmermann (eds.), *Los Saberes del Estado (*Buenos Aires, 2012), 185-212.
[110] Nispen, and Ravesteijn, 'The Road to an Empire', 40-57; Havik, 'Motor Cars and Modernity'.

traffic with asphalt paving and argued that the challenges that local conditions in the Indies imposed to road construction stimulated the creation of innovative solutions that not only did not lag behind metropolitan developments, but were even 'at least a decade ahead' of them.[111] These obstacles mostly consisted of a limited access to machinery and of various tropical environmental characteristics, which, along with an increasing motor traffic from the 1920s onwards, required the creation of new knowledge, skills and regulations.[112] The existence of a laboratory to test construction materials from 1912, the road programmes that started in 1914, and the use of asphalt from the 1920s onwards, were all considered as cutting-edge at the time.[113] Yet, as the authors note, there is no evidence that engineers in the Netherlands learned from the ones in the Indies.[114]

Freed also noted for the case of French central Africa that the introduction of increasingly heavy lorries in the 1920s put rising pressure on earth roads. She demonstrated that, however, unpaved 'low-budget' roads were considered ideal: they could respond to immediate needs while keeping down the expenses – since forced labour made maintenance costs negligible.[115] Freed noted how 'economic' roads continued to be preferred after the Second World War, with the difference that in the post-war period the colonial state invested heavily in road-building machinery and science research.[116] Nevertheless, she did not recognise how widespread this phenomenon was, nor the major role these roads played in transport systems across the developing world.[117]

These are isolated examples and the historiography has until recently told us little about the evolution of roads' technical characteristics and about the techniques and tools used to build and maintain them after 1945, when motorisation grew exponentially in the developing world. Katie Valliere Streit's recent thesis on mobility in today's Southern Tanzania during the twentieth century is an example of the important avenues that considering the materiality of roads can open. Studying the relationship between transport infrastructure and the economic, social and political life of the region, Valliere Streit shows that, despite being a symbol of marginalisation and impoverishment in the eyes of the state during both colonial and postcolonial times (a situation the state was partly responsible for), the seasonal dirt roads of

[111] Nispen and Ravesteijn, 'The Road to an Empire', 55.
[112] Nispen and Ravesteijn, 'The Road to an Empire', 54-55.
[113] Nispen and Ravesteijn, 'The Road to an Empire', 55.
[114] Nispen and Ravesteijn, 'The Road to an Empire', 55.
[115] Freed, 'Networks of (Colonial) Power', 217.
[116] Freed, 'Conduits of Culture and Control'.
[117] See also Chapter 1 and Maria Luísa Sousa, 'Colonial Centres and Peripheries: Low-Cost Roads and Portuguese Engineers in the 1950s', in Fari, Simone and Moraglio, Massimo (eds.), *Peripheral Flows: A Historical Perspective on Mobilities between Cores and Fringes* (Newcastle upon Tyne, 2016), 169-88.

Southern Tanzania nonetheless fostered the emergence of local dynamic socioeconomic initiatives.[118] In particular, in the late colonial period, Indian entrepreneurs created successful transport firms which quickly came to dominate the sector. Valliere Streit's research therefore illustrates the importance of paying attention to links that go beyond the metropole/colony dualism, as well as of recognising the implications of the material characteristics of roads. However, she does not attempt to make comparisons or connections with road development in other parts of the British Empire, and by focusing on the activities happening *on* the road she misses the story of the dynamic transnational adaptation of knowledge and practices that was at work in the construction and maintenance of the roads themselves.

The literature on twentieth-century roads in developing countries/colonies has therefore contributed to the examination of state power and exploitation, modernisation discourses, economic growth and activity, political and social struggles, and the cultural appropriation of motor vehicles. It has told us much less about roads, especially in the second half of the century. Since roads materialise particular visions of the state and economic development, they have not only fostered growth and facilitated integration, but they have also determined what sort of exchanges should be prioritised and which could be neglected, thus marginalising (both symbolically and physically) certain social groups and their interests. However, the very activities around the construction and maintenance of roads were closely linked to these processes of integration and fragmentation, and influenced their outcomes. The study of the materiality of the road also forces us to look beyond the familiar dualities of metropole/colony and centre/periphery. Thus the history of the road appears as necessarily global, not only because the motorable road spread worldwide, but also because it features international exchanges of money, people, knowledge and practices, machines and other objects, as well as the actions of public and private institutions and organisations with a wide international scope.

Moreover, only by problematising roads and taking seriously their materiality can we understand the specificity of roads (as compared to other transport methods) and begin to appreciate the distinctive and dynamic technological development of the developing world (see below). In fact, our accounts of twentieth-century roads need to tell us about unpaved roads, lorries and animal-drawn vehicles, machines and manual labour, laboratories and make-do practices, and, indeed, railways and ports. In addition, a comparative perspective outside the developed world allows us not just to extend the geographical scope of the current

[118] Katie Valliere Streit, 'Beyond Borders: a History of Mobility, Labor, and Imperialism in Southern Tanzania' (Univ. of Houston D. Phil. thesis 2016).

literature, but, above all, to highlight the transformation that roads and road transport experienced in the developing world in the post-war period.

Problematising materiality in the history of technology in the developing world

The historiography on technology in the developing world has been, since the 1980s and especially since the 1990s, mostly concerned with challenging what has been called the 'diffusionist approach'.[119] Critiques of this approach have placed its origins in the three-stage model of the spread of Western science elaborated by George Basalla in a short paper in 1967, and have denounced it for assuming a passive absorption of Western 'science' or 'technology' in the colonies.[120] Daniel Headrick is often identified as one of the major representatives of technological diffusionism. However, upon reflection, his arguments do not seem to merit this description. In his books, Headrick sets out to study the relationship between technology and European imperialism in the nineteenth and twentieth centuries. For him, certain European innovations (such as steamships and railways, weapons, and the prophylactic use of quinine) served different purposes in the process of colonisation as tools of penetration, conquest, and the consolidation of exploitative regimes.[121] By focusing on the transfer of these technologies as part of colonising initiatives, Headrick awarded little room to the study of the reactions of local populations to these innovations. Nevertheless, his objective was not to make a statement about technology in general, but about the technological means that shaped colonialism and that had, in the first place, made empire possible and cost-effective for the colonisers.[122] He also argued that the transfer of European technologies to the colonies was not accompanied by the diffusion of what he calls the 'culture of technology'.[123] By this he means that Europeans deliberately withheld significant technical knowledge from the colonised in an attempt to maintain their control over their colonial subjects. Although this

[119] I discuss here Anglophone historiography.
[120] That this model in fact embodied diffusionism is disputable. Basalla's argument revolved around the predominance of Western European scientific traditions and institutions, and around the steps through which other centres of scientific activity could emerge in different locations and compete with the established ones. It does not deal with scientific knowledge itself, but with the practices, activities, institutions, and objects that constitute the scientific tradition born in Western Europe in the sixteenth- and seventeenth-centuries. George Basalla, 'The Spread of Western Science', in *Science, New Series*, 156 (1967), 611-22.
[121] Daniel Headrick, *The Tools of Empire: Technology and European Imperialism in the Nineteenth Century* (New York, 1981).
[122] Headrick, *The Tools of Empire*, 11.
[123] Daniel Headrick, *The Tentacles of Progress: Technology Transfer in the Age of Imperialism* (Oxford, 1988).

argument assumes that technological knowledge had to be transferred from Europe to the colonies, the institutionalisation of the exclusion of colonised peoples from technical education and managerial positions, among other discriminatory measures, was a significant part of the technological history of the colonies. This was far from a diffusionist argument.

Critiques of technological diffusionism (an approach that seems to lack any significant representatives) have emphasised local agency, arguing that the adoption of any ‘technology’ requires an active process of appropriation from the colonised. Thus, for example, histories of colonial railways emphasise how local populations used trains in ways the colonisers did not always expect or approve of, and the ways in which these forms of socialisation spurred new social struggles and collective self-understandings, while they could also perpetuate existing inequalities.[124] Similarly, local agency has occupied a prominent place in studies of postcolonial contexts. Often in response to the state’s use of technologies as instruments of political power and legitimation, local populations have been portrayed in the literature as actors whose appropriation of technological innovations has frequently questioned and undermined the state (whether intentionally or not).[125]

Since most analyses focusing on local agency revolve around certain modern innovations that have been prominent in political discourses, large-scale schemes have been prominent in the literature. One of the responses to the widespread focus on large-scale technological projects in both colonial and postcolonial contexts was the turn to the ‘small’. In a special issue of *Modern Asian Studies* and in his book on everyday technology in colonial India, David Arnold presented a new perspective that seeks to focus on small-sized technologies that despite their apparent unimpressiveness in fact had a significant impact on the experience of everyday life in India, such as the typewriter, the sewing machine or the bicycle.[126] However, apart from the inclusion of small artefacts, this approach remains mostly concerned with highlighting the agency of local populations as users of imported innovations, and it is

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[124] See, e.g., Rudolf Mrázek, *Engineers of Happy Land: Technology and Nationalism in a Colony* (Princeton and Oxford, 2002); Manu Goswami, *Producing India: From Colonial Economy to National Space* (Chicago and London, 2004); Aparajita Mukhopadhyay, *Imperial Technology and 'Native' Agency, A Social History of Railways in Colonial India, 1850-1920* (London, 2018).

[125] For instance, in an article about postcolonial irrigation in Indonesia, Diane van Oosterhout shows that recently there has been a revival of a colonial small-scale irrigation technique (the waduk) that is claimed to be ‘traditional’ by Indonesian farmers and that is used as a positive referent to criticise current irrigation schemes led by the central authorities –despite the fact that it was never successful. Dianne van Oosterhout, ‘From Colonial to Post-Colonial Irrigation Technology: Technological Romanticism and the Revival of Colonial Water Tanks in Java, Indonesia’, in *Technology and Culture*, 49 (2008), 701-26.

[126] David Arnold and Erich Dewald, ‘Everyday Technology in South and Southeast Asia: An Introduction’, in *Modern Asian Studies*, 46, Special Issue (2012), 1-17; David Arnold, *Everyday Technology, Machines and the Making of India’s Modernity* (Chicago and London, 2013).

therefore unclear what this perspective adds to the historiography on technology in the developing world.[127]

In fact, perhaps concerned with staying away from the spectre of diffusionism, historians have tended to circumvent, rather than tackle, the issue of the movement of technological objects, knowledge and practices around the world. Studying the reactions of local populations (negative or not) to the introduction of foreign technologies (large or small) tells us little about how this movement happened. By concentrating on the relationship between colonisers and colonised, and state and local populations, other interactions and exchanges that go beyond these dichotomies have been neglected. Thus, exchanges within the developing world or extra-imperial connections have only recently started to receive attention, as well as the influence of the actions of colonial engineers back in the metropole.[128] Studying these exchanges can helps us advance our understandings of technology in the developing world without assuming that its significance is limited to the realm of the immaterial – as the focus on appropriation practices implicitly suggests.

Recently, some historians have adopted a material perspective that allowed them to move beyond commonly studied innovations and question existing historical accounts of the twentieth century. For example, in this PhD thesis, Kapil Subramanian called into question the picture the literature has painted of the so-called Green Revolution in India.[129] His research shows that High-Yielding Varieties did not play a role in the increased wheat yields of the 1960s and 1970s. In fact, the advantages of these seeds were only attainable at very high doses of inputs – and there is no evidence that any substantial section of Indian wheat cultivators applied a high-enough fertiliser dosage. Instead, the increase in yields was driven by an expansion in the area of wheat irrigated, a process that took place largely due to an increase in the number of privately-owned tubewells (and not due to public irrigation schemes). Subramanian therefore shows how taking materiality seriously allows us to deconstruct accounts based on assumptions of what the most significant technological innovations have been – thus yielding new understandings of technological change in the twentieth century. Another recent approach that seeks to take materiality into account, and

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[127] Arnold's interpretation of 'everyday technology' is in fact very similar to the way the historiography has studied agency within large-scale technological schemes: as objects or machines that could either enhance the power of the state, or provide tools to question and subvert it. Arnold, *Everyday Technology*, 172.

[128] See below and Casper Andersen, *British Engineers and Africa, 1875-1914* (London, 2011).

[129] Kapil Subramanian, 'Revisiting the Green Revolution: Irrigation and Food Production in Twentieth-Century India' (King's College London D. Phil. thesis, 2015).

move away from the innovation-centric histories that David Edgerton has criticised, is the move to study maintenance, which I will discuss below.

Maintenance

Maintenance is a topic that has received considerable attention from Science and Technology Studies (STS) scholars over the past three decades.[130] The influential work of the sociologist Susan Leigh Star represents an important example of the way in which maintenance work has been studied from the 1990s onwards. Star notes that one of the main characteristics of infrastructure is that it remains invisible until it breaks down.[131] For her, although maintenance is essential to guarantee the good performance of infrastructure, maintenance work is often taken for granted and thus rendered similarly invisible, which has important negative consequences for the workforce in charge of repairing and maintaining.[132]

Two major themes stand out in the way maintenance has been studied more recently: first, how commonplace and necessary it is for the stability of social and material orders, and second, its link with innovation and transformation. In a 2007 article, for example, Stephen Graham and Nigel Thrift call for the study of maintenance and repair not just because these activities are part of modern societies, but because they are the very processes that keep them going: 'Repair and maintenance are not incidental activities ...they are the engine room of modern economies and societies'.[133] For them, maintenance is connected to innovation because over time new objects and techniques are created to perform it, and because repair can generate the invention of solutions that go beyond the original objectives of the designer. Graham and Thrift also state that there is a politics of maintenance. Not only do different ways of maintaining produce distinct outcomes which are more or less efficacious, some objects are less maintainable than others.

More recently, Steven Jackson linked the notion of maintenance with 'broken world thinking' to argue that repairing is the action that determines the growth and advancement of complex

[130] For a more complete picture of the way maintenance has been studied in STS see Jérôme Denis, Alessandro Mongili, and David Pontille, 'Maintenance and Repair in Science and Technology Studies', in *Tecnoscienza, Italian Journal of Science & Technology Studies,* 6 (2015), 5-15.
[131] Susan Leigh Star and K. Ruhleder, 'Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces', in *Information Systems Research*, 7 (1996), 111-34.
[132] Mark Zachry, 'An Interview With Susan Leigh Star', in *Technical Communication Quarterly*, 17 (2008), 435-54.
[133] Stephen Graham and Nigel Thrift, 'Out of Order. Understanding Repair and Maintenance', in *Theory, Culture & Society,* 24 (2007), 19.

sociotechnical systems.[134] For him, once we appreciate the natural, social and technological fragility of the world we are able to recognise that maintenance is the activity that keeps modernity from falling apart. Yet, although repair and maintenance are essential for stability, they are also transformative forces. Breakdown generates innovative solutions that are, in the end, the ones that make sociotechnical systems expand and improve. Jackson also suggests that maintenance can be understood as a main source of technological difference. According to him, in contrast with 'working technologies', breakdown and repair are often 'the aspects or portions of broader technological systems that show the most variation across national, cultural, or other comparative contexts'.[135]

The sociologists David Pontille and Jérôme Denis also start from the recognition of the material fragility of the world. They present maintenance work as a 'care practice' because it is an activity that recognises and acts on the fact that vulnerability is the natural state of things and people (and not a temporary deviation).[136] They emphasise that maintenance can be both transformative and restorative, and they highlight the importance of improvisation and skill in maintenance work. In fact, for them continual adaptation is required in maintenance because it is not possible to predict in advance what work will be needed, and the 'skilled vision' of the worker is necessary to judge what activities are necessary.[137]

In general, maintenance has been presented as an activity that is detached from the design stages. Even when maintenance is seen as innovative, and breakdown presented as providing essential feedback, the way in which technologies are designed (more or less) maintainable has attracted less attention. An exception is an article by the anthropologist Marianne de Laet and the political philosopher Annemarie Mol on a hand water pump produced in Zimbabwe. They point out that in the case of this pump, adaptability was built into the design, and the resulting flexibility of the pump was the factor that facilitated its widespread adoption.[138] Tinkering and maintenance were therefore not incidental but essential to the design and subsequent success of this artefact.

[134] Steven J. Jackson, 'Rethinking Repair', in Tarleton Gillespie, Pablo J. Boczowski, and Kirsten A. Foot (eds.), *Media Technologies: Essays on Communication, Materiality, and Society*, (Massachusetts, 2014), 221-39.
[135] Jackson, 'Rethinking Repair', 227.
[136] Jérôme Denis and David Pontille, 'Material Ordering and the Care of Things', in *Science, Technology, & Human Values*, 40 (2015), 338-67.
[137] Denis and Pontille, 'Material Ordering and the Care of Things', 357.
[138] Marianne de Laet and Annemarie Mol, 'The Zimbabwe Bush Pump: Mechanics of a Fluid Technology', in *Social Studies of Science*, 30 (Apr. 2000), 225-63.

Historians of technology have also started to include maintenance and repair in their analyses.[139] An important example is the work of Lee Vinsel and Andrew Russell. By focusing on maintenance they seek to highlight the 'work that goes into preserving technical and physical orders'.[140] Although these authors recognise the fact that maintenance is creative, their approach highlights the role of users and that of the workforce in charge of performing routine repair and maintenance tasks.[141]

Maintenance has become a dynamic topic in the history of technology field. Vinsel and Russell created 'The Maintainers' conference in 2016, and maintenance has acquired a more prominent space at the annual meetings of the Society for the History of Technology (SHOT).[142] International workshops dedicated to maintenance have also emerged, attracting both young and prominent scholars.[143] Broadly speaking the topics that have attracted the most attention are the maintenance and repair of objects, machines and certain large-scale systems (such as the electrical and telephone ones), routine maintenance/care of homes, cities, bodies and animals, and maintainers as an undervalued workforce. However, other themes have received limited attention such as the maintenance and maintainability of infrastructures, the role of professional engineers in keeping things working, and the influence of income in the way maintenance is done and the role it acquires.

Experts in the history of development

Scientific and technical experts have long been prominent actors within histories of development. In his well-known book *Seeing Like a State*, James Scott studies a few examples of large social engineering projects of the twentieth century (such as agricultural and villagization schemes) and seeks to explain why they failed. These projects originated, according to him, from the desire of authoritarian states to control their people and

[139] Simon Schaffer, for example, explores in a recent article the maintenance and repair of nineteenth-century scientific instruments. He concludes that repair can be transformative and that it relies more on artisan tinkering than on formal norms. Simon Schaffer, 'Easily Cracked: Scientific Instruments in States of Disrepair', in *Isis,* 102 (December 2011), 706-17. See also Edgerton, *Shock of the Old*.
[140] Andrew Russell and Lee Vinsel, 'After Innovation, Turn to Maintenance', in *Technology and Culture,* 59 (January 2018), 7.
[141] Andrew Russell and Lee Vinsel, 'Hail the maintainers', in Aeon.co https://aeon.co/essays/innovation-isovervalued-maintenance-often-matters-more (25/03/2018)
[142] See The Maintainers website http://themaintainers.org/ (10/09/2019). I presented a paper at a SHOT session entitled 'Maintaining Natures' in 2017.
[143] I participated in a workshop organised by Stefan Krebs and Heike Weber called 'Histories of Technology's Persistence: Repair, Reuse and Disposal' at the University of Luxembourg in 2018 along with scholars such as Philip Scranton and David Luckso.

environment, and from their faith in a 'high modernist ideology', i.e. confidence in an uncritical version of scientific and technical progress mostly preoccupied with the aesthetics of modernism.[144] The realisation of the schemes was only possible due to the combination of a state willing to use force and coercion to bring high-modernism, and the existence of a weakened society uncapable of resisting the State. For Scott, the schemes failed first because high-modernism relied on making peoples and environments 'legible' for the state, which implied the simplification of complex realities, a process that ultimately prevented any real understanding of the local conditions. Second, experts ignored or actively attempted to eliminate local knowledge both because of prejudice and as a way to undermine local populations.[145] Along similar lines, Timothy Mitchell examined large techno-political projects linked with modernisation or development initiatives in Egypt in the twentieth century and linked their failure with the experts' inability to anticipate problems.[146]

Although Scott has been widely criticised for the peripheral place he provided to the agency of local populations, authors such as Helen Tilley and Suzanne Moon have questioned the argument that development projects and their experts were always large-scale schemes that ignored local knowledge and had no understanding of the complexities of local conditions.[147] Both authors belong to a recent trend in the history of development which sees the origins of development practices and ideas not in the post-war period, but in earlier colonial efforts.[148] In her study of the Netherlands East Indies in the late colonial period, Moon shows that the technological development programmes that emerged at the time were based on small-scale schemes that had a (biased) interest in local practices and knowledge, and a certitude that the combination of Western technologies with an 'understanding' of indigenous people would guarantee the improvement of the welfare of the subject population.[149]

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[144] James C. Scott, *Seeing like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, 1998), 4-5.
[145] Scott, *Seeing like a State,* 6, 286.
[146] His case studies included dams and other projects to change the flow of the Nile, irrigation schemes and the use of artificial nitrates and synthetic chemicals in agriculture. Timothy Mitchell, *Rule of Experts: Egypt, Techno-Politics, Modernity* (Berkeley and London, 2002).
[147] Helen Tilley, *Africa as a Living Laboratory: Empire, Development and the Problem of Scientific Knowledge, 1870-1950* (Chicago and London, 2011); Suzanne Moon, *Technology and Ethical Idealism: A History of Development in the Netherlands East Indies* (Leiden, 2007).
[148] See below.
[149] Similarly, Daniel Immerwhar recently argued that the development projects promoted and financed by the US from the 1930s to the 1960s did not always revolve around large-scale, top-down transformations. In fact, these development efforts were always confronted to a rival inclination: the 'quest for community', i.e. an 'effort to shore up small-scale social solidarities, to encourage democratic deliberation and civic action on a local level, and to embed politics and economic with the life of the community. Its adherents preached the values of grassroots democracy and recognized the ways in which traditional institutions could protect their members from the economic and political shocks of

Tilley on the other hand argues that from the mid-nineteenth to the mid-twentieth century certain scientific disciplines in British colonial Africa not only did not ignore local knowledge, but actually stressed the heterogeneity of the colonies' environments, and the complexity of the interrelations among the various problems they studied.[150] Although scientists ultimately worked to 'modernise' Africa, they sought ways of achieving this that highlighted site specificity and even local knowledge.[151] Although the work of these scientists did not necessarily change the views of policymakers or the direction of scientific and technical work in the colonies, it did open the door for a positive consideration of African expertise, and for a critique of the way empire worked in practice.[152] Moreover, Tilley points out that even though scientific structures and activities were cognisant of empire, international intergovernmental organisations and private philanthropies also had a significant influence on the activities of colonial scientists, especially American ones.[153]

Another move against the model proposed by Scott has been to question the overarching power that he attributed to experts, and the coherence of development discourses and practices. For example, in his recent book about the Gezira scheme in Sudan, Mauritus Ersten argues that this project needs to be understood as a process that was mediated by both European colonial officials and African farmers.[154] Ersten proposes to see development schemes as the result of constant negotiations that, although unequal, nuance the power of the colonial state by highlighting the agency of colonial subjects and especially that of colonial officials and engineers, who all had individual agendas. In addition, the actions of the latter were continually conditioned by the environment and were often the result of improvisation rather than calculated planning and flawless execution.[155] Improvising, experimenting, and using make-do practices in road development do appear as important activities in the developing world, where particular restrictions in terms of machinery, equipment, and

modernization'. Daniel Immerwahr, *Thinking Small: The United States and the Lure of Community Development* (Cambridge, 2015), 2-4; Moon, *Technology and Ethical Idealism*.

150 A similar argument was made by Christophe Bonneuil about British and French colonial scientists. See Christophe Bonneuil, 'Development as Experiment: Science and State Building in Late Colonial and Postcolonial Africa, 1930-1970', in *Osiris*, 15 (2000), 258-81; Tilley, *Africa as a Living Laboratory*, 5.

151 For example, agricultural researchers started from the interwar period to push back against the wholesale transfer of European norms to African environments and introduced the study of Africans' subaltern or orally transmitted agricultural knowledge. Tilley, *Africa as a Living Laboratory*, 5, 122.

152 Tilley, *Africa as a Living Laboratory*, 123.

153 Tilley, *Africa as a Living Laboratory*, 7-10.

154 Ersten Mauritus, *Improvising Planned Development on the Gezira Plain, Sudan, 1900-1980* (New York, 2016), 8.

155 Ersten, *Improvising Planned Development*, 12.

materials, as well as challenging climatic and topographic conditions (and even factors such as long distances and isolated road sites) required the provision of such solutions.

Moreover, Ersten and other authors have noted that portions of the local populations were also able to take some advantage from development schemes by using them for their own purposes. Expectations about economic benefits often surrounded road projects, even in colonial times.[156] For example, the historian Marcus Filippello points out that the mechanisation of road construction in the post-war period changed the perception of a local community in Dahomey (French West Africa) towards road projects led by the colonial authorities.[157] Although at first wary of the project to rebuild a road in the late 1940s, the local community soon saw in the improved road surface an opportunity to facilitate the transport and commercialisation of their goods, and in the use of earth-moving machinery a way of avoiding strenuous work.[158] Thus, the community not only welcomed the reconstruction works, but in fact demanded that the authorities build an additional road that would join the ongoing road project, offering to help with its construction on a voluntary basis.[159] By contributing to road construction, the members of the community did not feel they were recognising their status as colonial subjects, but, on the contrary, they considered they were confirming their sense of independence.[160]

As Uribe illustrates, the political and economic meaning that roads acquired for local populations in independent contexts also led them to actively demand the construction and maintenance of roads.[161] Finally, as the anthropologists Penny Harvey and Hannah Knox show, in the twenty-first century not only roads in general, but roads with all-weather surfaces in particular, are still generally seen today as infrastructures holding promises of social, political and economic benefits, especially in sparsely populated areas (whether or not those expectations are fulfilled is a different issue).[162]

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[156] See also Freed, 'Conduits of Culture and Control' and Valliere Streit, 'Beyond Borders'.
[157] Marcus Filippello, *The Nature of the Path: Reading a West African Road* (Minneapolis and London, 2017).
[158] Filippello, *The Nature of the Path*, 91-105.
[159] Filippello, *The Nature of the Path*, 104-05.
[160] In fact, although colonial authorities had previously called for the expansion of maize production for commercial purposes, it was only when the new road allowed the community to enter this market on their own terms that they decided to do so. Filippello, *The Nature of the Path*, 106-07.
[161] Simón Uribe, *Frontier Road: Power, History, and the Everyday State in the Colombian Amazon* (Hoboken, New Jersey, 2017).
[162] Penny Harvey and Hannah Knox, *Roads: An Anthropology of Infrastructure and Expertise* (Ithaca, New York, 2015). There are of course exceptions to the positive view of road projects as we have seen above. Another important example is that of indigenous groups that wish to remain isolated from certain dynamics that motorised transport brings. Land resettlement is another issue that could generate reactions against road projects but given the scale chosen for this research this aspect will not be studied.

The thesis: major interventions, structure and sources

This thesis responds to Mom's call for the study of the technical aspects of roads and advances the historiography that takes into account the materiality of roads, which until now consisted of isolated examples. Thus, this thesis presents for the first time a comparative account of twentieth-century road construction and maintenance in Latin America, Africa and Asia – an area whose road development has largely gone unnoticed. Instead of simply adding new cases, this thesis recognises the major role roads played in these areas and seeks to paint a general picture of the major characteristics of road development in this period. This approach reveals complex exchanges and interactions at a global scale that considerably advance our understandings of the way knowledge and technologies have moved around the world.

Taking the material seriously gives maintenance a central place in this thesis. Building on new studies of maintenance, I argue in this thesis that maintenance is relevant not only because it refers to the use and upkeep of technology, but also because it is a highly innovative area in itself. Understanding innovation in maintenance, and its significance not least to professional engineers, reminds us that maintenance has not been just a matter of low status routine work. The case of roads shows that maintenance was a central concern (albeit in different form) in all stages of road development: from planning and construction, to use and upkeep.[163] My thesis therefore provides elements to understand how intertwined technological maintenance and innovation are. In fact, road maintenance in the developing world was closely related to improvement and therefore did not aim to keep things the same, but indeed to create something new. Ultimately, new construction and maintenance were both a question of state/colonial power and economic success. Yet, maintenance was usually neglected in the face of funds scarcity. Who maintains, who pays for it, and with what objective are questions that can yield new insights into our understanding of the link between infrastructure technologies and power at different scales.

The shape that infrastructural development projects took on the ground is a subject that is attracting increasing attention, and this thesis aims to advance the study of the mutual

163 The importance that maintenance acquired in this thesis is also a result of the sources used. Although I note the importance of the private sector, I have mostly focused on road-related governmental activities, which were mostly linked to maintenance, as construction was usually performed by private firms.

interactions between the natural environment and transport infrastructures.[164] Considerations about the natural environment are necessary in every stage of any road project: from planning and design, to construction and maintenance. Indeed, it is difficult to talk about a road without mentioning topographic or climatic conditions since any road directly transforms its surrounding area while the environment, in turn, constantly modifies the road itself. These interactions are intertwined as the effect of the road upon the natural environment can in turn generate other effects on the road. For instance, the deforestation, the extensive earth movement, and the use of explosives involved in the construction of a road in a mountainous area, can cause erosion and destabilise the terrain, thus increasing the risk of landslides. This is not specific to the developing world, but the distinct interaction between environmental and work conditions made for particular problems that were rarely found in developed countries.

The serious consideration of environmental factors allows me to build on Tilley's arguments in two ways. First, this thesis highlights the fact that the complexity of local environments was at the heart of the road engineer's concerns. Road design, maintenance, construction materials (and the way these were employed) were all directly affected by environmental conditions and road engineers were aware of the difficulties of adapting knowledge produced in different conditions, and worked towards finding the most appropriate solutions to fit every site. In addition, although road engineers could sometimes use local knowledge to learn about the terrain or certain drainage techniques, in general the construction of motorable roads was a novel task that required the production of new knowledge, especially about soils. Unprecedented traffic densities, as well as the proliferation of heavier (and more heavily loaded) vehicles (both new motorised and animal-drawn) generated particular demands that roads were not previously meant to answer.

Analysing the way in which this need to produce new knowledge was satisfied yields new insights into the way techniques, practices and equipment were produced and moved across the world. The predominance of American road-related techniques from the 1930s onwards, but especially after the Second World War, point to the need of taking into account exchanges

[164] See Jonas van der Straeten and Ute Hasenöhrl, 'Connecting the Empire: New Research Perspectives on Infrastructures and the Environment in the (Post)Colonial World', in *NTM Zeitschrift Für Geschichte Der Wissenschaften, Technik Und Medizin* (2017), 1-37. For an overview of recent studies combining environmental history and STS in general see Sarah B. Pritchard, 'Joining Environmental History with Science and Technology Studies: Promises, Challenges and Contributions', in Dolly Jorgensen, Finn A. Jorgensen, and Sara B. Pritchard (eds.), *New Natures: Joining Environmental History with Science and Technology Studies* (Pittsburgh, 2013), 1-20.

beyond commonly studied relationships (such as metropole-colony) as well as of considering the dynamics of professional technical networks both at the local and international scales.

Moreover, the influence that colonial engineering activities had in the metropole has also started to attract some attention. As Casper Andersen noted for the case of British engineers in Africa in the nineteenth and early twentieth centuries, the experience of colonialism was felt in the growing importance of the central engineering institutions, in the business platforms from which leading figures of the profession worked, and in the public and self-perceptions of the civil engineers.[165] This thesis shows with the case of the French materials laboratories that the experience engineers acquired in the colonies shaped the development of road engineering techniques and related scientific institutions in France after 1945 – an experience that was, in turn, influenced by the work of the US Army Corps of Engineers.[166]

Finally, this thesis also follows recent histories of development such as those by Tilley, Moon, and Joseph Hodge in identifying the roots of development in colonial times, and highlighting the continuities that such discourses and practices had in the postcolonial period.[167] Following this vision of development in the long-term makes evident continuities between the colonial and postcolonial periods, as well as opens the door to the comparison of (post)colonial Africa and Asia with Latin American nations in the twentieth century. In fact, as Hodge pointed out for the case of colonial agricultural and natural resource experts, this thesis notes that colonial road engineers were also found working for international organisations such as UNESCO or the World Bank in the postcolonial period.

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[165] Andersen, *British Engineers and Africa*.

[166] The influence of American capital and expertise in Ivory Coast especially after independence, but also from the post-war years onwards, was pointed out by Abou B. Bamba in his discussion of the construction of the Kossou dam in the late 1960s. Abou B. Bamba, 'Triangulating a Modernization Experiment: The United States, France and the Making of the Kossou Project in Central Ivory Coast', in *Journal of Modern European History,* 8 (March 2010), 66-84. See also André Guillerme, 'Le Contexte de la Création des Laboratoires Régionaux des Ponts et Chaussées (1945-1955)', *in L'Aventure des Laboratoires Régionaux des Ponts et Chaussées, Colloque du Cinquantenaire* (28 Nov. 2002).

[167] Over the last two decades or so, a new literature on the history of development has started to see development as a framework of ideas and practices that did not emerge after the Second World War, but which had its origins in earlier colonial efforts. For an example of development as a product of the post-war era centred around the US see Gilbert Rist, *The History of Development: From Western Origins to Global Faith, 3rd ed.* (London and New York, 2008). For a review of recent trends in the history of development see Joseph M. Hodge, 'Writing the History of Development (Part 1: The First Wave)', in *Humanity: An International Journal of Human Rights, Humanitarianism, and Development,* 6 (2015), 429-63; Joseph M. Hodge, 'Writing the History of Development (Part 2: Longer, Deeper, Wider)', in *Humanity: An International Journal of Human Rights, Humanitarianism, and Development,* 7 (March 21, 2016), 125-74.

This thesis is divided into five chapters. The first two chapters offer a global perspective of road construction and maintenance around the world from 1930 to 1970, focusing on the developing world and on the post-1945 period. Chapter 1 provides a global overview of the general trends of road development. It first presents the massive growth that road transport and networks experienced, not only in Europe and the US, but also, significantly, in Latin America, Africa and Asia. This growth involved high proportions of unpaved roads and heavy traffic. This chapter suggests that maintenance and improvements (rather than the expansion of road networks) were the main factors that allowed for the rise of heavy traffic after the war – an argument that is further developed in Chapters 3 to 5. Chapter 1 also briefly considers the issue of why roads acquired such importance within the transport systems of the developing world in that they could compete with, and sometimes surpass, railways as carriers of goods. I suggest here that the arguments that were put forward in favour of road development were generally not linked to superior technical efficiency or the reduction of transport costs, but were instead connected to their relatively low initial investment, their flexibility, and the possibility they offered of responding to transport demands without having optimal standards. Further, I argue that due to the rising transport demands and the limitations of funds, a particular type of road became widespread in the developing world: the low-cost road. Built keeping costs to a minimum to the detriment of quality standards and circulation conditions, this type of road increased the risks of needing future expensive reconstruction and maintenance works. However, it provided a quick and relatively cheap solution and this justified the construction of roads that would need reconstruction or considerable repairs faster than they would have done if they were built with normal standards. This chapter ends with a brief account of the evolution of the definition of the low-cost road and its key characteristic: upgradeability.

After the first chapter has presented the general trends and logic behind road development, the second chapter explores *how* the latter took place, focusing on the period after the Second World War, when the rising traffic densities required faster and more efficient road construction and maintenance tools and techniques. This chapter argues that, from 1930 to 1970, and especially after 1945, road construction in Latin America, Africa and Asia was transformed by American road-building approaches adapted to different contexts. In fact, road development in these areas cannot be understood without taking into account the work of a growing international road engineering community that adapted and combined American approaches with others, coming from both Europe and other developing countries. Given the varied and peculiar conditions in some of these countries and colonies, these adaptations were highly innovative and went from the creation of artefacts, to the modification of construction techniques due to the use of different materials or due to the type of traffic (sometimes including high proportions of animal-drawn vehicles). Organisational and managerial capacities seem to have adapted at a slower pace than engineering techniques to the new and growing demands, and the limitations of the former often represented a considerable obstacle for the adoption of certain tools and methods. Finally, this chapter suggests that apart from shaping construction and maintenance, scarcity of funds justified the deferral of certain solutions considered ideal and the application of palliative measures.

The remaining chapters of the thesis present three case studies: the main road networks of French colonial Africa, Argentina, and Colombia. These cases were chosen because of their complex relationship between roads and large railway networks, and their particularly challenging environmental conditions. Prioritising these factors contributes to my objective of taking seriously the competition between the two land transport methods, as well as the interactions of roads with the natural environment.

The chapter on French colonial Africa focuses on French West Africa and the Algerian Sahara from the Second World War until independence.[168] Both territories were highly important for the metropole in economic, political, and military terms. Rising transport demands prompted the adoption of American modern road-building and maintaining machines and techniques. Private firms played an important role in this process and in the development of road engineering in general during colonial times. This chapter examines roads in two distinct environmental contexts that represented particular challenges for the French civil engineers. However, the chapter suggests that it was the engineers' lack of knowledge about the environments (and more precisely about how to build roads in those contexts), rather than the conditions themselves, which made these particularly challenging. Despite the engineers' interest in using local knowledge (as they did by, for example, employing artesian wells in the Sahara), often this knowledge was not translatable for their particular purposes, which was to build and maintain motorable roads.

Unlike the rest of the case studies in this thesis, the section on the Algerian Sahara focuses on construction and deals with very expensive paved roads. The exploration for and exploitation of hydrocarbons in the Sahara created dynamics that differentiated this context from the rest of the French empire. In contrast, in French West Africa in the post-war period a regime of mechanised maintenance was established to ensure the circulation of lorries on

[168] This chapter does not study the postcolonial period although my research suggests a high degree of continuity after independence.

low-cost roads that were mostly unpaved – phenomena comparable to the developments that characterised the cases of Argentina and Colombia in the 1950s and 1960s, albeit at a different scale.

Although the discussion on French West Africa starts to explore the issue of road/rail competition, the Latin American cases provide a more in-depth reflection on this topic, in territories served by large railway systems (especially in Argentina) but with different economic histories and geographical contexts. Although both countries adopted an inward-looking model of economic development after the Second World War, Argentina's growth in the first three decades of the century, as well as the success of its industrialisation policies in the 1950s and 1960s, put the country in a much better position than Colombia by 1970 – although the latter also experienced high rates of GDP growth during the period.[169] Nevertheless, from 1945 to 1970, both countries suffered from constant balance-of-payments problems, inflation, and political instability.

Argentina's economic growth, aided by its comparatively easy topography, had left the country with a transport infrastructure and traffic densities that competed with those of Western Europe by the 1930s. However, from the middle of the century, the road authorities started to struggle to respond to the increasing transport demands with the funds at their disposal. In fact, from 1950 to 1970, roads consolidated their predominance as the main carriers of goods. Chapter 4 examines how the national road authorities responded to these demands. I argue that Argentina's national road network was able to withstand rising lorry traffic after 1945 mostly due to maintenance and improvement works, as well as to the shift from building mostly seasonal roads to building almost exclusively all-weather roads. I further suggest that the success of these developments was facilitated by the previous building and maintenance experience that road authorities and construction firms had acquired since the interwar years. I first briefly present the road building experience of the 1930s and 1940s, highlighting the influence of the American model in the construction of concrete and low-cost roads, as well as in the mechanisation and creation of materials laboratories and use of soil mechanics principles. I then explore the challenges that the road authorities had to face in the post-1945 period: rising road freight traffic and the scarcity of funds resulting from the state's inability to adapt tax legislation to accommodate growing inflation, and to its

[169]Argentina's rate of growth of GDP at constant prices was 2.8 per cent from 1950 to 1960, and 4.4 per cent from 1961 to 1970. Colombia's was 4.6 per cent from 1950 to 1960, and 5.2 per cent from 1961 to 1970. As Bulmer-Thomas argues, in general, the rate of growth of Latin American GDP compared favourably with other developing countries (as it was higher than that of East Asia) and was faster than the rate of growth in the developed countries. Victor Bulmer-Thomas, *The Economic History of Latin America since Independence, 3rd ed.* (New York, 2014), 330-36.

prioritisation of the interests of a state-owned energy company. After presenting the varied road policies adopted during the period, this chapter ends by showing how the materialisation of these policies was built on the modernisation efforts of the previous two decades.

In contrast to the Argentinian case, on top of financial difficulties, the Colombian state had to deal with the challenges of a rugged topography and a tropical climate. The country's environmental diversity could be seen as offering the possibility of building a complex intermodal transport system. Nevertheless, although in 1950 roads and railways were carrying the same amount of freight, by 1970, roads surpassed railways like in the previous case study. Chapter 5 explores how the Colombian national road infrastructure was able to withstand such growing traffic. It argues that since the state was unable to coordinate the transport methods at its disposal, it put increasing pressure on the road network, and maintenance and improvements ended up being the factors that allowed for the growth of traffic – even if it was not the state's policy to prioritise road repairs. The chapter also illustrates how administrative and organisation issues hindered road development in developing countries. Unlike Argentina, Colombia did not experience an early modernisation of road construction and maintenance. Therefore, although new machines and techniques were adopted, the Ministry of Transport's failure to coordinate maintenance, supervise construction, and provide clear technical standards limited considerably the effectiveness of its efforts. However, roads could still allow the circulation of traffic (even if slow and expensive) in the context of funds scarcity, a poorly planned transport policy, and poor maintenance conditions, which seems to have put them in an advantageous position in front of railways.

These three chapters show roads acquiring a considerable share of the transport of goods in contexts with both small and large railway networks, with different economic conditions, in colonial and independent settings. Natural environments determined the costs and influenced the methods and demands of road development, but lorries carried goods over long distances, deserts, steep mountains, and under heavy rains. Paving advanced significantly, but by 1970 main trunk networks still featured a high proportion of unpaved roads, and some main routes were not paved continuously.

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This thesis is the result of research conducted in five different countries, in over ten repositories, in three different languages, and based on archives produced by road engineering associations and conferences, public administrations, and the World Bank. Given the centrality awarded to materiality, the main sources used were road engineering publications and congress reports. Apart from national engineering publications, the Permanent International Association of Road Congresses (PIARC) provided a valuable perspective of the state of road engineering in the world, although concentrated in Europe and its colonies. Figures about the evolution of road lengths are far from uniform and comparisons are difficult to make. Not only did road categories vary greatly between countries/colonies, they also did over time in the same territory. Since the evolution of vehicle fleets also presented similar problems, I have prioritised sources that present data and information in a relatively systematic way, such as those from the International Road Federation (IRF) and the World Bank's Staff Appraisal Reports. Even though the PIARC reports and proceedings, as well as the World Bank reports and several other documents, are freely available online their use has been minimal in the historiography. Other significant sources were the archives of the British Road Research Laboratory (RRL) and the library of the American Highway Research Board (HRB) found, respectively, at the National Archives in London (United Kingdom) and the National Academies of Science, Engineering, and Medicine (Washington D.C., US). Several archives and libraries in France, Argentina and Colombia were used for the case studies. The material used corresponded not only to engineering publications but also to the archives of the ministries of public works or their equivalent.

Chapter 1 Low-cost roads: an overview of road development in the developing world, 1930-1970

This chapter presents an overview of road development from 1930 to 1970 based on my own analysis of the sources. As I have noted, the historiography has no account of the scale or type of road building in this period and has focused on very particular aspects. Starting from a global perspective, this chapter focuses on Latin America, Africa and Asia.[1]

In the developing world, the rates of growth of motor vehicles in use and road length extension were fast. The growing road networks were mostly unpaved during the period, and often carried a high proportion of heavy vehicles. Road transport was increasingly competing with railway networks for the transport of goods over long distances, a phenomenon that was facilitated by the rising deficit and declining condition of railways. In addition, roads started to be preferred over railways for new construction, mainly because they required lower initial capital investment, but also because they were able to function with low quality standards and were relatively easier to upgrade over time.

Given the rising transport demands during the period, in order to build as many kilometres of road as possible with limited funds, a particular type of road became widespread in the developing world: the low-cost road.[2] These roads were meant to last longer than wartime supply routes, but half as long as the main roads of the developed world were designed to last. The provisional character of low-cost construction in the developing world was not questioned, it was an integral part of the advantages that made it attractive. The low-cost road was built keeping costs to a minimum to the detriment of quality standards and circulation conditions. Such roads also increased the risk of needing future expensive reconstruction and maintenance works. However, the life of the roads and the conditions of circulation depended on whether routine maintenance and timely improvements were carried out – and it was difficult to plan this in advance, as neither road engineers, nor the new experts involved in

[1] Unless otherwise stated, the Eastern Bloc is not included. Middle Eastern countries appear occasionally.
[2] In a recent edited volume, Maria L. Sousa notes the use of the term 'low-cost road' at the 1950s Permanent International Road Association Congresses by French, British and Portuguese engineers. However, she does not explain in detail what this type of road entailed in practice, nor does she study how widespread the concept was or the important influence of American standards, methods and tools for the construction and maintenance of this type of road (see below and Chapter 2). Maria Luísa Sousa, 'Colonial Centres and Peripheries: Low-Cost Roads and Portuguese Engineers in the 1950s', in Simone Fari and Massimo Moraglio (eds.), *Peripheral Flows: A Historical Perspective on Mobilities between Cores and Fringes* (Newcastle upon Tyne, 2016), 169-88.

the appraisal of road projects were able to accurately predict future conditions (especially traffic growth). When many roads built in the early 1950s were in need of reconstruction a few years after being built, their failure was not a surprise, although the speed at which it arrived was. Although low-cost roads were also built in the developed world, they acquired a much more important role within transport systems in the developing world.

Even though this chapter presents the growing use and length of low-cost roads, it also points out that road length tells us little about the rising load-bearing capacity of these roads. The maintenance and upgrades of roads' surfaces and structures are at the centre of the story of road development, especially after the Second World War. This chapter presents the link between low-cost roads and upgradeability, and Chapters 3 to 5 illustrate the importance that maintenance and improvements acquired in parts of the developing world in which road expansion was relatively limited in the post-1945 period.

The first section of the chapter starts with a brief description of the general trends of road development from 1930 to 1970. Section 2 examines the motives behind road development concentrating on why roads started acquiring such a large role within land transport systems, competing against railways, and sometimes even replacing them as main carriers of goods. A few examples are presented to illustrate this phenomenon and its relation to the amounts invested in road development by national or colonial governments. This section introduces the question of what type of arguments in favour of road development seem to have been influential within road engineering circles and the World Bank.[3] I argue that the advantages of roads, especially when discussing freight traffic, were generally not linked to technical efficiency or a reduction of transport costs, but were instead connected to their relatively low initial capital requirement, their flexibility, and the possibility they offered of serving traffic under technical conditions that were not optimal.

The last section discusses the concept of the low-cost road. After briefly explaining what I consider to be a temporary road through the example of the work of the US Army Corps of Engineers during the Second World War, I examine the relationship between upgradeability and the design life of the low-cost road.[4] Despite the changing meaning of the concept of

[3] This section does not attempt to provide a comprehensive study of this phenomenon since such an endeavour would require the analysis of topics such as the lobby from the petroleum and motor vehicle industries, the pressure from private enterprises ranging from small transport carriers to large multinational companies, and the struggles to maintain and modernise railway networks in a changing global geo-political climate, amongst many others.
[4] The example of the US Army Corps of Engineers is also relevant given how influential their work during the Second World War was around the world, see Chapter 2.

upgradeability from the early-1950s to the late-1960s, and despite the lack of consensus on how it was best applied, an implication of its adoption became increasingly apparent: this type of road was inherently linked to a future plan of engineering works and expenditure that was hard to plan given the difficulty of predicting the evolution of certain conditions, such as traffic growth. Therefore, low-cost roads were not only a palliative solution, they were also an option that increased the risk of facing high costs of maintenance and reconstruction in the (not-so-distant) future.

The data used to illustrate the evolution of railway and road transport, as well as the growth of road and rail networks come mostly from the world statistics of the International Road Federation (IRF) and from the World Bank's Staff Appraisal Reports of road and rail projects during the period. As previously mentioned, the figures are not precise and are only meant to give an idea of the magnitude of the phenomena discussed. The reports of the Permanent International Association of Road Congresses (PIARC) meetings and varied documents that the World Bank has made available online were also useful. Although the World Bank was not the only international funding agency involved in road projects at the time, it was one of the most important ones and had a wide geographical scope. The section on road construction during the Second World War (in this chapter and the following one) was mostly based on two official histories of the US Army Corps of Engineers: *Troops and Equipment* and *War Against Japan*, although an official training film from the Defense and War Departments found online was also a valuable source.

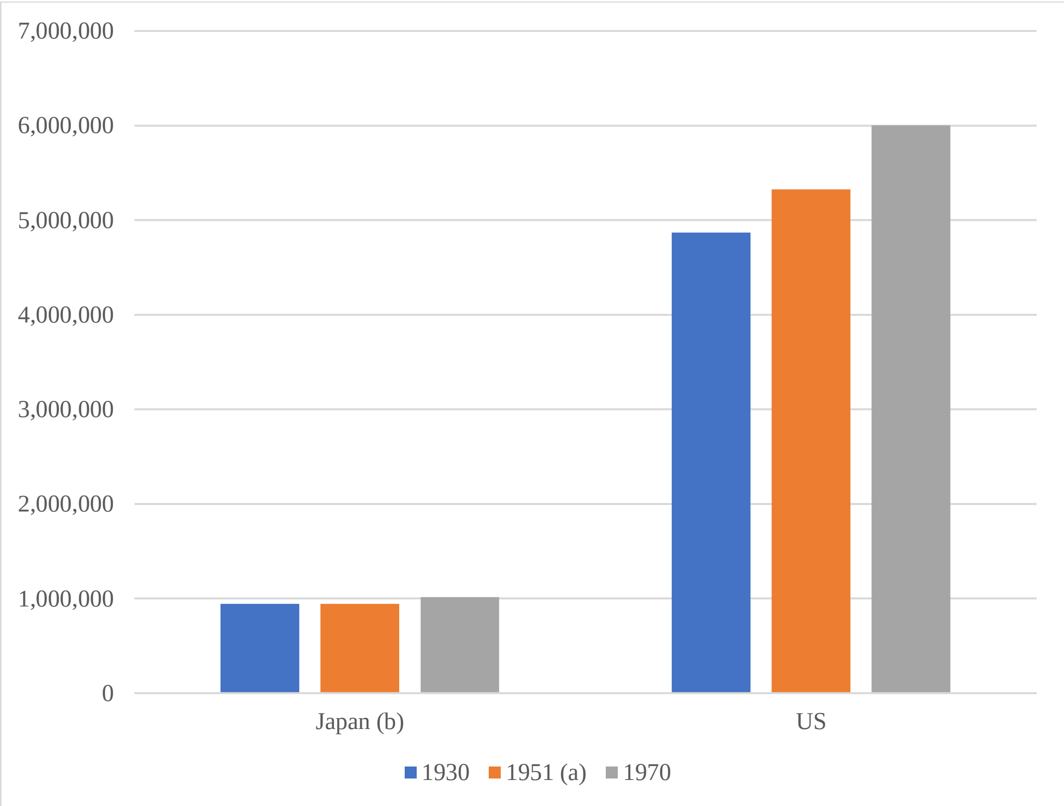
The rise of motor vehicles, the rise of the road

Although measuring the rise of road transport is not as straightforward as evaluating the growth of other transport methods, such as railways, the increase of both road lengths and motor vehicles in circulation can give an estimation of the growing significance of roads. The US was the leading country of motorisation and road expansion throughout the period. By 1930, the US had about twenty times as many motor vehicles in circulation than France and Great Britain – the countries with the highest number of motor vehicles in use outside the US at the time.[5] By 1952, the number of vehicles in use in the US had increased rapidly and the country had by far the largest number of vehicles in circulation per capita (337.4 vehicles per

[5] The US had about 26.5 million motor vehicles in circulation, while Great Britain and France had 1.4 million and 1.3 million respectively. International Chamber of Commerce (ICC), *A Statistical Survey of World Highway Transport* (Paris, 1931), 12-13, 14-15.

1,000 inhabitants, against 68 and 54 in Great Britain and France respectively); by 1970 the US continued to have the largest fleet, although Western Europe and Japan were starting to catch up.[6] The US also had the largest road network of the world throughout the period; in fact, Japan's network, the second largest by 1970, amounted to approximately 1 million km of roads, while the US had about 6 million km (see Graph 1.1). In comparison with our case studies, the US had, in 1930, approximately 106 times more kilometres of roads than French West Africa, 139 times more than Algeria, 22.8 times more than Argentina, and 157 times more than Colombia.[7] By 1951, although some countries such as France, Great Britain and Belgium had longer networks in relation to the size of their territories, the US had the highest road length per 100,000 population – i.e. 3,949 km, followed by Argentina with 2,589 km.[8]

Graph 1.1 Road length in Japan and the US in 1930, 1951 and 1970 (km)



(a) Figure for Japan is from 1956.

[6] In 1970, the US had about 529 motor vehicles in use per 1,000 inhabitants, while Great Britain and France had about 244 and 281, respectively. Japan had significantly increased its number of vehicles, and followed closely with 171 vehicles per 1,000 inhabitants. International Road Federation (IRF), *World Road Statistics, Revised Second Edition* (London, 1953), 16, 118-20; IRF, *World Road Statistics, 1967-1971* (London, 1972), 52-54, 66-69.
[7] See Annexe A.
[8] See Annexe A.

(b) Figures for Japan from 1930 and 1956 include city, town and village streets.

Sources: International Chamber of Commerce, *A Statistical Survey of World Highway Transport* (Paris, 1931), 18-19 (hereinafter: ICC, *A Statistical Survey)*; International Road Federation (IRF), *World Road Statistics, Revised Second Edition* (London, 1953), 13; IRF, *World Road Statistics, 1967-1971* (London, 1972), 19; Statistics Bureau, Ministry of Internal Affairs and Communications, Japan, Historical Statistics, Chapter 12 Transport, Table 12-4 Length of roads and paved roads (CY 1894—1935, FY 1936—2004) Available at http://www.stat.go.jp/english/data/chouki/12.html (06/06/2019).

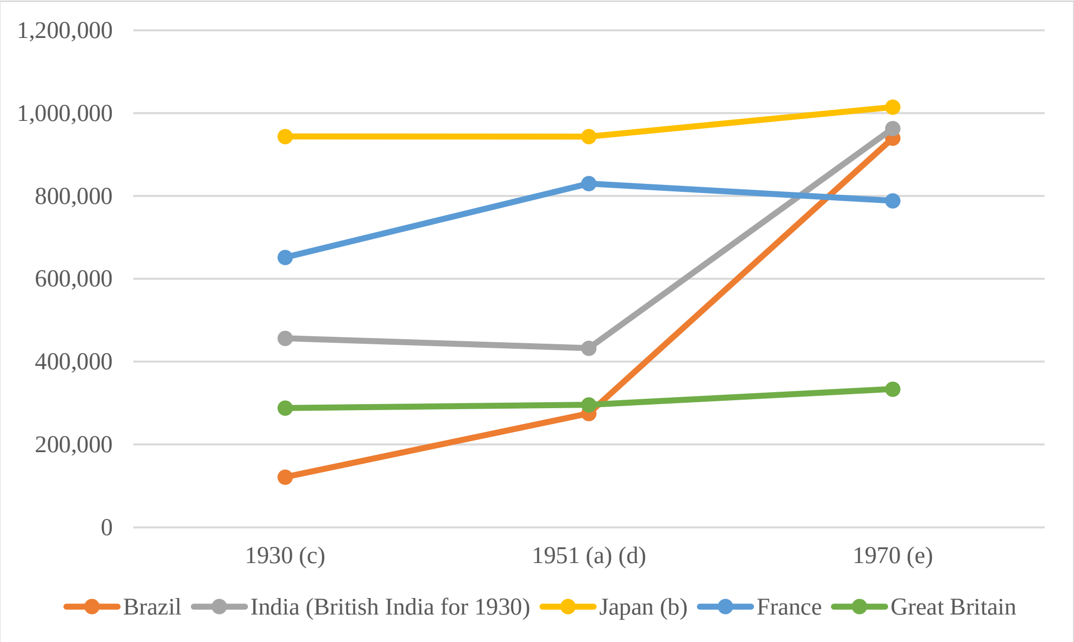
From 1930 to 1970, outside the US, Japan and Western Europe, the countries with the largest road networks throughout the period were India and Brazil (see Graph 1.2). In 1928, British India had about 337,600 km of roads, and by 1952, independent India had around 432,800 km (although this figure includes urban roads), and by 1967 the network almost doubled with about 884,159 km.[9] In Brazil, while in 1930 there were 113,253 km of roads, in 1948 there were about 416,800 km and in 1967 the number doubled to 826,425 km.[10] This meant that, by 1970, India and Brazil had larger road networks than France and Great Britain (See Graph 1.2). The extension of road networks in India and Brazil was certainly related to the considerable size of their territories. The densities of roads per square kilometre in these two countries were considerably lower than the densities in France and Britain: 0,29 km and 0,10 km of road per square km in India and Brazil respectively, in contrast to 1,42 km and 1,45 km in France and Great Britain.[11] In fact, the density of road networks in relation to geographical area in the developing world was, in general, markedly inferior to that of developed countries, even by 1970. For instance, as Annexe A shows, in 1970, countries such as Ivory Coast, Chile, and Indonesia had, respectively, a road density of 0,10 km, 0,09 km, and 0,04 km per square km; while Italy, Great Britain, and France had road densities that went from 0,95 km to 1,45 km per square km, and Japan, the country with the densest network after Belgium, had 2,74 km of road per square km.[12]

The rate of growth of road lengths in the developing world was in some cases considerably faster than in Western Europe, Japan and the US during the period (see Graph 1.2). In fact, in general in the 1930s road networks were expanding despite the limiting effects of the Great Depression, and although networks continued to grow during the 1940s, in some countries

[9] ICC, *A Statistical Survey*, 20-21; IRF, *World Road Statistics, Revised Second Edition*, 13; IRF, *World Road Statistics, 1967-1971*, 19.
[10] ICC, *A Statistical Survey*, 18-19; IRF, *World Road Statistics, Revised Second Edition*, 14; IRF, *World Road Statistics, 1967-1971*, 18.
[11] See Annexe A.
[12] In 1970, Belgium had 3 km of road per square km. See Annexe A.

the rate of construction was particularly rapid after the Second World War, often as a result of programmes of nation building (especially in the case of Brazil).[13] In general, in this period road, not railway, building was a core part of nation building. The road networks of certain (ex)colonies also grew considerably after 1950 (such as Nigeria, Malaysia and Uganda), albeit to a significantly smaller scale, as Annexe A shows. In fact, the massive post-1945 growth of Brazilian and Indian roads seem to have been rather exceptional.[14] Several countries and colonies experienced relatively limited road length expansion after the Second World War, and in particular the cases studied in this thesis (Chapters 3 to 5). For instance, while the length of Colombia's total road network experienced an increase of about 120 per cent from 1951 to 1970 (with the construction of about 24,200 km of roads), during the same period Brazil's total road length increased by approximatively 240 per cent (with the construction of about 664,400 km of roads).[15]

Graph 1.2 Road length in selected countries in 1930, 1951 and 1970 (km)



(a) Figure for Japan is from 1956.

(b) Figures for Japan from 1930 and 1956 include city, town and village streets.

[13] See Joel Wolfe, *Autos and Progress: The Brazilian Search for Modernity* (New York, Oxford, 2010).
[14] In some countries the length of road networks appears to decline over certain periods of time (such as Argentina and Mexico, see Annexe A). This could be related to the disrepair of roads, but was also often linked to administrative changes in the way road lengths were measured (see Chapters 4 and 5). In particular, urban roads (streets) and tracks or earth roads were sometimes included and sometimes excluded from national statistics of road networks.
[15] See Annexe A. In Colombia, the expansion of the national network (excluding Departmental, Municipal and other categories) was much slower. From 1951 to 1970, only 7,400 km of national roads were built, corresponding to a 60 per cent increase. See Chapter 5 and Annexe O.

(c) Figures for France and India are from 1929.

(d) Figures from France and India include urban streets.

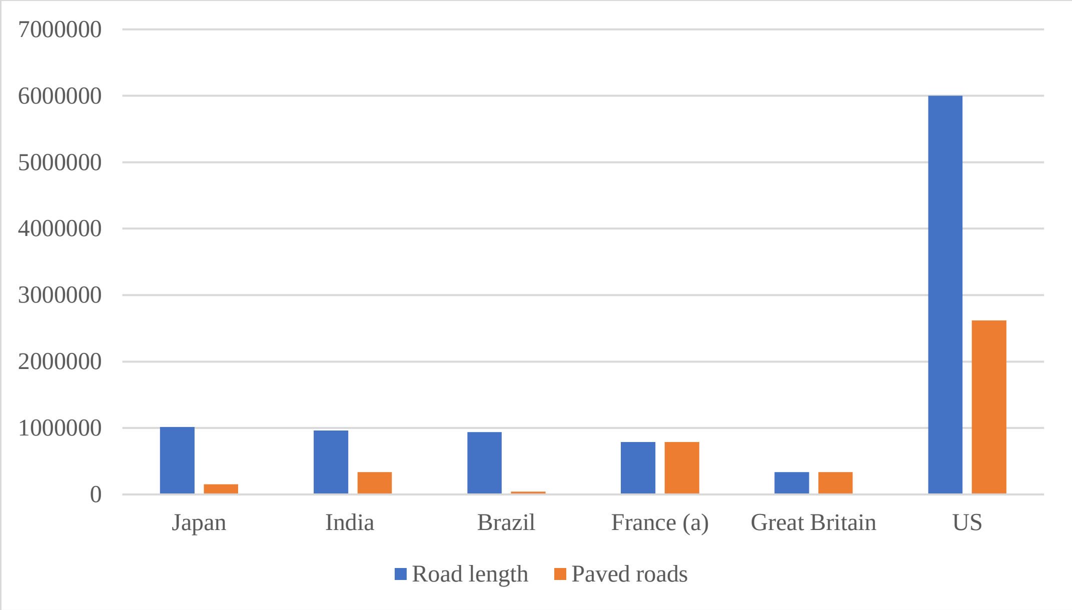
(e) Figure from France excludes 698,000 km of rural roads.

Sources: ICC, *A Statistical Survey,* 18-23; IRF, *World Road Statistics, Revised Second Edition,* 11-14; IRF, *World Road Statistics, 1967-1971,* 10-26; Statistics Bureau, Ministry of Internal Affairs and Communications, Japan, Historical Statistics, Chapter 12 Transport, Table 12-4 Length of roads and paved roads (CY 1894—1935, FY 1936—2004) Available at http://www.stat.go.jp/english/data/chouki/12.html (06/06/2019).

Figures about road length and density tell us little about the characteristics and conditions of roads, and therefore about their load-bearing capacity. However, data about road surfaces can provide a general idea about road characteristics. Roads during this period were mostly unpaved (see Graph 1.3), especially in the developing world.[16] In fact, by the late 1960s there were very few countries with a majority of paved roads: Great Britain, Luxemburg, the Netherlands, Austria, and France; which were also countries with relatively dense road networks in relation to their area.[17] Even as late as 1971, a country like Brazil, which by then had a network of 1,138,444 km and a growing and increasingly industrialized economy, only had 5 per cent of its roads paved.[18] India, a country that also experienced a significant post-war industrial expansion, had by 1971 about 983,000 km of roads and only 35 per cent of them were paved.[19] Graph 1.3 shows that Japan also had a small proportion of paved roads and, even in the US, where in 1971 there were 6,003,007 km of roads, 55 per cent of the roads were unpaved.[20]

Graph 1.3 Total and paved roads in selected countries in 1970 (km)

[16] These figures refer to the road networks in general, and not just to new roads built during the period.
[17] IRF, *World Road Statistics, 1967-1971*, 12-22.
[18] IRF, *World Road Statistics, 1967-1971*, 19.
[19] IRF, *World Road Statistics, 1967-1971*, 19.
[20] IRF, *World Road Statistics, 1967-1971*, 18.



(a) Figures exclude 698,000 km of rural roads.

Source: IRF, *World Road Statistics, 1967-1971*, 10-26.

Considerable paving did take place during the period, especially after 1945. As the case studies of Colombia and Argentina illustrate (Chapters 4 and 5), the portion of the national road network (which consisted of the most important roads at a national level) that was paved passed from less than one per cent in Colombia and no more than 10 per cent in Argentina in the early 1950s, to about 24 per cent in Colombia and 44 per cent in Argentina in the late 1960s.[21] Yet, these two cases also stand as an example of the fact that most road networks in the developing world (both main and secondary) were still mostly unpaved by 1970.[22] It is difficult to determine how much traffic unpaved roads were carrying in relation to the paved ones, as traffic surveys were rare during the period. It is likely that the roads which carried the most traffic were paved, at least by late 1960s. However, as Chapters 4 and 5 show, certain important routes connecting large cities or production areas to other cities or international ports were not continuously paved even in the late 1960s.[23] Moreover, in developing countries

[21] Dirección Nacional de Vialidad, *Panorama Vial de la República Argentina, Situación Actual de la Dirección Nacional de Vialidad* (Buenos Aires, 1970), Fig. 14, 27; Álvaro Pachón and Maria Teresa Ramírez, *La Infraestructura de Transporte en Colombia Durante el Siglo XX: Una Descripción desde el Punto de Vista Económico* (Bogotá, 2006), Anexo II.37.

[22] A few exceptions were Malaysia, Morocco, and Mexico to a lesser extent, see Annexe A.

[23] In Colombia, for example, there were no continuous paved roads between the centre of the country (where the capital is located) and the coasts, even in 1969. In Argentina, several national road stretches carrying on average 100 vehicles per day were not paved in 1960 (especially, but not exclusively, those roads located relatively far from Buenos Aires, such as those in Patagonia). For instance, the road between Neuquén and Mendoza was unpaved for about half of its length (and it was even just a track at the outskirts of Neuquén, where traffic was the heaviest), despite carrying 100 vehicles per day on

and colonies, lightly trafficked roads often served high proportions of heavy vehicles. This means that even when traffic density was low, roads could carry relatively high proportions of lorries or other types of heavy vehicles (such as tractors, trailers, etc.), the circulation of which caused severe degradation even in relatively small numbers, as Chapter 2 explains in more detail.

The growth of road networks was spurred by a massive increase in motor traffic, which was particularly rapid in Latin America, Asia and Africa.[24] In the most motorised country, the US, the number of registered vehicles went from 23,386,542 in 1928 to 51,291,600 in 1952.[25] In less developed countries the rate of traffic increase was in some cases faster. In Brazil, for instance, the number of vehicles trebled, from 136,000 in 1928 to 488,900 in 1952.[26] By 1970, the number had risen to over 3 million vehicles (see Graph 1.4).[27] As another example, in the Gold Coast there were about 7,500 registered vehicles in 1939 and by 1957 (when it became the independent Republic of Ghana) there were approximately 35,480 vehicles, about 4.7 times as many in less than twenty years.[28] Although the rise in the number of vehicles in circulation was less rapid in the 1960s, by 1973 Ghana had about 1.6 times more vehicles in use than in 1957 (i.e. 56,000 vehicles).[29]

Graph 1.4 Estimated number of vehicles in circulation in selected countries in 1930, 1952 and 1970 (in thousands of vehicles)

average in 1961. Moreover, the road network in the north of the country was poorly connected, as Santiago del Estero and San Miguel de Tucumán were not connected by any continuous paved roads with the rest of the country by 1961. Considerable paving took place in the 1960s, but Santiago del Estero and San Miguel de Tucumán were still only connected by unpaved roads with Corrientes, and although the road between Neuquén and Mendoza was mostly paved, there was still a significant stretch whose surface was just 'natural' earth. Herman Felstehausen, *Conceptos de Planeamiento Para Mejorar Carreteras y Caminos Colombianos* (Bogotá, 1969), 17; Annexes I, J, K.

[24] See also Annexe C.

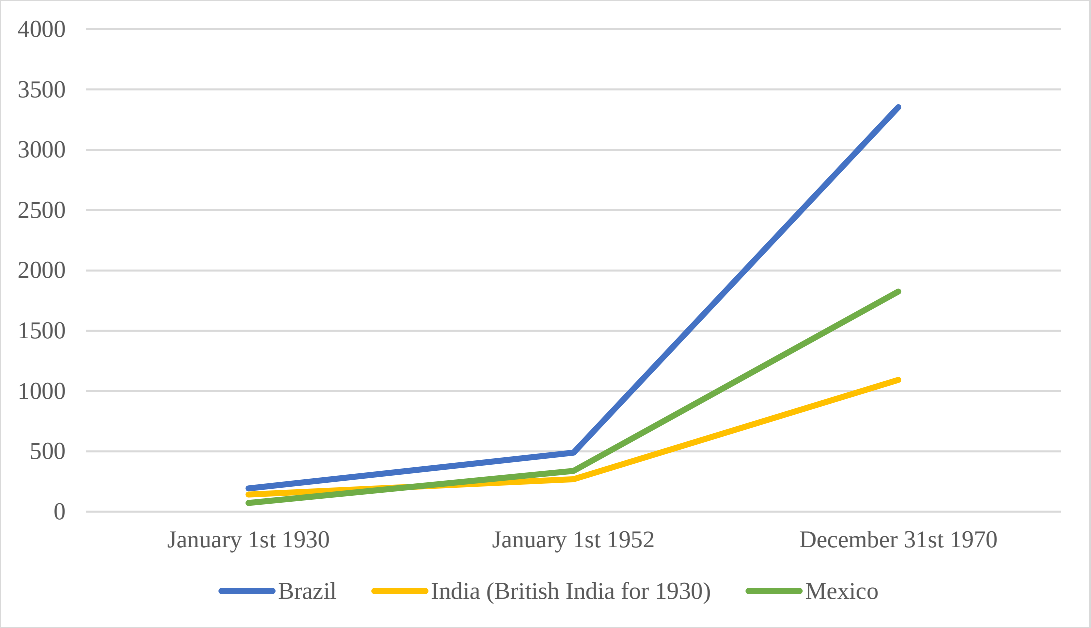
[25] ICC, *A Statistical Survey*, 12-13; IRF, *World Road Statistics, Revised Second Edition*, 17.

[26] ICC, *A Statistical Survey*, 12-13; IRF, *World Road Statistics, Revised Second Edition*, 18.

[27] IRF, *World Road Statistics, 1967-1971*, 18.

[28] Ifor Wyn Pugh and Jan Kanty Wardzala, 'Mechanization of Road Construction in Ghana, 1952-57', in *Conference on Civil Engineering Problems Overseas, 1958* (London, 1958), 85-108.

[29] IBRD, IDA, 'Appraisal of a First Highway Project, Ghana' (Washington D.C., 29 June 1973), 6.



Sources: For Brazil, in 1970 the exact date is not specified. This figure is an estimate done by the Grupo Executivo de Integração da Política de Transportes (GEIPOT) in 1970 quoted in IBRD, IDA, 'Appraisal of a Third Construction Project, Brazil' (Washington D.C., 29 February 1972), Table 9. See also: ICC, *A Statistical Survey*, 18-23; IRF, *World Road Statistics, Revised Second Edition*, 11-14; IRF, *World Road Statistics, 1967-1971*, 10-26.

After the Second World War, in most places outside the developed world traffic density oscillated between 300 and 2,000 vehicles per 1,000 km of road (while most developed countries had a density between 1,000 to 3,000 vehicles per 1,000 km of road).[30] However, in some cases, traffic density could surpass the densities commonly found in Western Europe and the US. In 1952, for instance, while France and Britain had a traffic density of 2,700 and 11,600 vehicles per 1,000 km of road respectively, in the Federation of Malaya there were about 7,600 vehicles per 1,000 km of road.[31] In the same year, in Panama (four years after the creation of the Colón Free Trade Zone) there were about 16,000 vehicles per 1,000 km of road.[32] These were not negligible densities, especially because an important proportion of this traffic was related to goods transport.

In fact, lorries were central to motor traffic outside the developed world in general. Already in the 1930s there was a significant number of lorries in countries such as Argentina and Brazil. For example, in January 1930, at the beginning of Getúlio Vargas' interventionist

[30] IRF, *World Road Statistics, Revised Second Edition*, 119-120.
[31] IRF, *World Road Statistics, Revised Second Edition*, 118-120.
[32] IRF, *World Road Statistics, Revised Second Edition*, 118.

regime, it was estimated that there were about 64,560 lorries in use in Brazil, which represented about 33 per cent of the total of motor vehicles.[33] This number had more than tripled by 1952, and Argentina experienced a similar growth passing from about 80,200 lorries in 1930 to 128,300 in 1952 – period in which lorries passed from representing 19 to 35 per cent of the total of motor vehicles in use.[34] This traffic growth was related to the industrialisation policies that both countries undertook in this period, starting with imports substitution during the Great Depression (although agricultural production was also significant, especially during the Second World War).

In the developing world, the proportion of automobiles was typically low by US and European standards. In the US, for instance, there were around 42,570,500 private cars and 8,721,100 commercial vehicles in 1952.[35] In contrast, in Mexico, for example, there were in 1952 about 193,100 private cars and 127,000 commercial vehicles.[36] In some cases the number of commercial vehicles surpassed the number of private cars. This was the case for the Gold Coast, Nigeria, French West Africa, Madagascar, Tanganyika, Angola, the Belgian Congo, and Latin American countries like Bolivia and Ecuador (see Graph 1.5). In French West Africa, for instance, there were in 1952 approximately 12,900 private cars and 26,700 commercial vehicles.[37] By the late 1960s, the proportions of heavy vehicles as compared to private cars were less stark but were still significant since there were about twice as many private cars than goods vehicles in most cases.[38] This is a point which bears expansion. Lorries and pickups were considerably larger and heavier than automobiles. For example, the 1960 Ford Falcon, 4-door sedan, 109.5-inch wheelbase, weighed about one ton, and generally carried less than 500 kg.[39] In contrast, a 1957 Ford F-600 dump truck had a maximum gross vehicle weight of about 8,500 kg, and some versions of the 1958 Ford T-850 had a maximum

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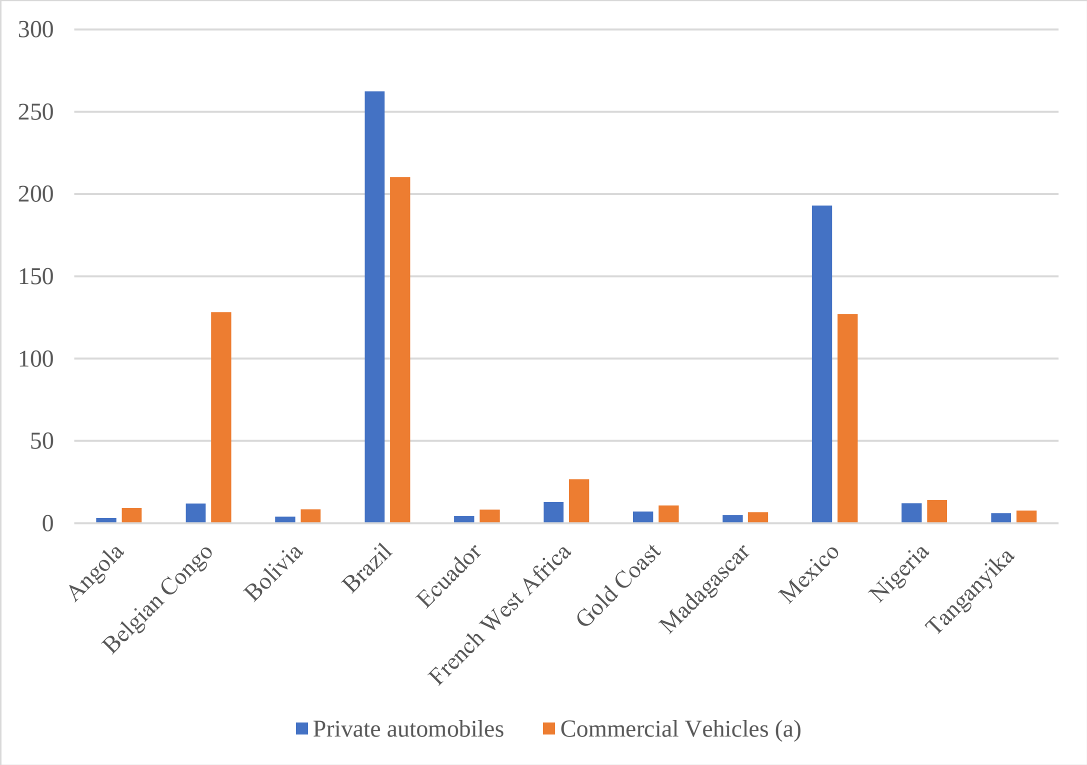
[33] ICC, *A Statistical Survey*, 12-13.
[34] ICC, *A Statistical Survey*, 12-13.
[35] In its 1953 edition, the IRF's World Road Statistics distinguished between private cars, passenger vehicles (i.e. buses and coaches), and commercial vehicles, defined as: 'all mechanically-propelled vehicles of a load-carrying type – trucks, lorries, ambulances, fire engines and all such vehicles employed in Government or Municipal services (excluding buses and coaches)'. IRF, *World Road Statistics, Revised Second Edition*, 15, 17.
[36] IRF, *World Road Statistics, Revised Second Edition*, 17.
[37] IRF, *World Road Statistics, Revised Second Edition*, 16.
[38] See Annexe C.
[39] 1960-1965 Ford Falcon Specifications https://auto.howstuffworks.com/1960-1965-ford-falcon13.htm (17/09/2019).

gross vehicle weight of about 20,400 kg.[40] High proportions of lorries and other goods vehicles were therefore particularly damaging for roads (see Chapter 2).

Graph 1.5 Estimated number of private cars and commercial vehicles in circulation in selected colonies and countries, January 1952



(a) Commercial vehicles were defined by the IRF in 1953 as: 'all mechanically-propelled vehicles of a load-carrying type – trucks, lorries, ambulances, fire engines and all such vehicles employed in Government or Municipal services (excluding buses and coaches)'. Figures for Angola, Gold Coast, Nigeria and Tanganyika include buses and coaches.

Source: IRF, *World Road Statistics, Revised Second Edition*, 15-18.

Finally, roads in some parts of Asia and the Americas also had to accommodate the rising traffic of animal-drawn vehicles.[41] The case of India is perhaps unique due to the high number

[40] The unit of gross vehicle weight includes the vehicle's chassis, body, engine, engine fluids, fuel, accessories, driver, passengers and cargo but excludes that of any trailers. James K. Wagner, *Ford Trucks Since 1905* (Sarasota, 1978), 278, 289.

[41] This seems to have been less common in the Americas. However, the high number of animal-drawn vehicles was considered a safety hazard in some British territories in the Caribbean in the early 1950s. That was the case of Barbados in 1953, where it was estimated that there were approximatively as many private cars as animal-drawn vehicles in circulation. National Archives United Kingdom (NA), Department of Scientific and Industrial Research (DSIR) 27/331, RN/2553/PHPW, PHP Williams, Roads and Road Problems in the Caribbean Area (July 1955), 11-12.

of bullock carts circulating throughout the twentieth century. In 1961, the International Development Association (IDA) stated that animal-drawn carts and other slow moving vehicles were a main feature of road traffic in India.[42] According to the IDA, these vehicles tended to outnumber motor vehicles on traffic surveys, even on the National Highways.[43] That same year it was estimated there were more than 10 million bullock carts, while there were about 160,000 lorries, 50,000 buses, and 285,000 cars, jeeps and taxis.[44] About 500,000 of the bullock carts were commercial, which means they were hired to carry goods for a reward.[45] The number of these vehicles was expected to continue to grow as it had been doing in the 1950s, following an increase of the farmers' income.[46] Indeed, in 1971, slow moving traffic (including bullock and hand carts) was still a decisive factor for road construction and maintenance, although its presence on trunk roads was decreasing.[47] Studies had been carried out to examine the effects these carts had on traffic operations, concluding that in terms of road capacity one bullock cart was the equivalent of 11.2 passenger cars.[48]

Roads over railways

In the second half of the twentieth century, roads acquired increasingly important roles within transport systems in many countries and colonies – a process that had often started in the 1930s. In most Latin American countries, with the exception of Bolivia, roads replaced railways as main carriers of goods, even in long distances, and even in countries with extensive rail systems like Argentina and Colombia (Chapter 4 and 5).[49] In Brazil, for

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[42] International Development Association, 'Appraisal of a Road Project for India' (Washington D.C., June 1961, I-2 (hereinafter: IDA, 'Appraisal of a Road Project for India').
[43] IDA, 'Appraisal of a Road Project for India', I-2.
[44] IDA, 'Appraisal of a Road Project for India', I-2.
[45] IDA, 'Appraisal of a Road Project for India', I-2.
[46] IDA, 'Appraisal of a Road Project for India', I-2.
[47] This trend was believed to be caused by the increased competition of motor vehicle traffic that accompanied road development. Dr. Bh. Subbaraju et. al., 'Question 4 The Road in Relation to Traffic Requirements, India', in *PIARC* (Prague, 1971), 4.
[48] In addition, it was found that one hand cart was the equivalent of 2.8 passenger cars. Road capacity refers to flow, rather than load-bearing capacity. Subbaraju et. al., 'Question 4 The Road in Relation to Traffic Requirements, India', 4.
[49] Bolivia's railway length doubled from 1924 to 1960 (from about 2,000 km to 4,100 km) and railways maintained the largest share of international goods traffic by far from 1950 to 1970. Road development was late in comparison to most Latin American countries and the road network played a small role in international freight during the period. In fact, by the early 1970s, roads only carried about 5 per cent of international commerce. Unlike most Latin American countries, foreign investment on railway development in Bolivia came from Brazil and Argentina. Carmen Aycart Luengo, 'Los Ferrocarriles de Bolivia, Perú y Chile, una Aproximación a la Historia de los Andes entre 1850 y 1995' in Jesús Sanz Fernández (ed.), *Historia de los Ferrocarriles de Iberoamérica 1837-1995* (Madrid, 1998), 103, 109.

example, the proportion of ton-km carried by rail decreased from 28 per cent in 1950, to 18.3 per cent in 1961, and to 14.4 per cent in 1968.[50] In contrast, the proportion of ton-km carried by road went from 41.6 per cent in 1950, to 62.9 per cent in 1961, and to 72.6 per cent in 1968.[51] Despite the nationalisation of the Brazilian railways, which started in the 1930s and was accelerated after the Second World War, and despite the impulse that the war gave to the railways due to the difficulty of importing motor fuel, railways became less important.[52] According to the historian Ángel Rodríguez Carrasco, the Brazilian state turned to roads as prime movers of goods in great part because the railway network had been built to export mineral and agricultural products and was therefore outward-looking and lacked many connections between lines.[53] In fact, in 1968, roads carried 107.5 billion of net ton-km, while railways carried 21.4 billion of net ton-km.[54] A degree of specialisation did take place, and from 1960 onwards railways tended to mostly carry minerals, fuel, and construction materials, amongst other similar products.[55]

The increasing importance of roads within national transport and economic policies in Latin America in the second half of the century was also evident in the way public investment was divided. In the case of Brazil for instance, federal investment in railways in relation to the other transport methods went from representing 32.37 per cent in 1965 to 13.7 per cent in 1969, whereas investment in roads grew from 38.67 per cent to 46.52 per cent during the same period.[56] Peru provides an extreme example, with railways being attributed only 1.8 per cent of the budget in the transport investment plan for 1961-1971.[57] This low figure is in great part explained by the fact that, unlike most Latin American countries, Peru did not nationalise its railway network until after 1970, which, combined with the rising identification of railways as a symbol of European imperialism after the Second World War, resulted in a limited governmental effort to support railway transport.[58] In fact, according to the historian

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[50] IBRD, IDA, 'Appraisal of a Second Highway Construction Project, Brazil' (Washington D.C., 17 March 1970), Table 1 (hereinafter: IBRD, 'Appraisal of a Second Highway Construction Project, Brazil'); Ángel Rodríguez Carrasco, 'El Ferrocarril y la Economía en Brasil', in Jesús Sanz Fernández (ed.), *Historia de los Ferrocarriles de Iberoamérica 1837-1995* (Madrid, 1998), 205.
[51] IBRD, 'Appraisal of a Second Highway Construction Project, Brazil', Table 1; Rodríguez Carrasco, 'El Ferrocarril y la Economía en Brasil', 205.
[52] Rodríguez Carrasco, 'El Ferrocarril y la Economía en Brasil', 205.
[53] Rodríguez Carrasco, 'El Ferrocarril y la Economía en Brasil', 205.
[54] IBRD, 'Appraisal of a Second Highway Construction Project, Brazil', Table 1.
[55] Rodríguez Carrasco, 'El Ferrocarril y la Economía en Brasil', 205.
[56] IBRD, 'Appraisal of a Second Highway Construction Project, Brazil', Table 3.
[57] Aycart Luengo, 'Los Ferrocarriles de Bolivia, Perú y Chile', 107.
[58] Aycart Luengo, 'Los Ferrocarriles de Bolivia, Perú y Chile', 105.

Carmen Aycart Luengo, the state introduced a tax on the railways specifically to fund road development in the middle of the century.[59]

A preliminary overview of road and rail transport in Asia and Africa in the post-1945 period suggests that the shift from rail to road was not as marked as it was in Latin America.[60] Roads did carry larger freight volumes than railways in many cases. For instance, in Ivory Coast, already in 1951, about 60 per cent of the two most important export products of the territory (coffee and cacao) were transported by lorry and not by rail (see also Chapter 3).[61] This trend continued after independence and, by 1973, 70 per cent of inter-urban freight traffic (ton-km) was carried by road, while only 25 per cent was carried by train.[62] Another example is Nigeria, where the share of tonnage carried by road to and from the port of Lagos increased from 16 per cent in 1955 to 60 per cent in 1967-68.[63] The rise of road traffic around this port in the late 1960s was related to the damages the railway suffered in the context of the civil war that had started in 1967.[64] Large quantities of general cargo and petroleum products were shifted to the roads – which started deteriorating due to an unprecedented high volume of heavy traffic and a general lack of maintenance.[65] In Indonesia, railways were carrying mostly passengers by the late 1960s. The World Bank estimated in 1969 that the railway's share of the transport of goods by land was below one tenth of the total.[66] Over the previous six years, only 15 per cent of the traffic on the railway corresponded to freight.[67] According to the Bank, railway track and bridge maintenance had been neglected since 1939, and by 1969 the vast majority of the rolling stock was over 40 years old, 75 per cent of the locomotives were steam-powered and the service to shippers was slow and unreliable.[68] The maintenance condition of the railway seems to have played a role in the decline of rail traffic, and the volume of ton-

[59] The state also purposely built roads parallel to railway lines since the 1930s, but the competition between rail and road was considered to be beneficial for the service of both methods. Aycart Luengo, 'Los Ferrocarriles de Bolivia, Perú y Chile', 105-107.
[60] This could be related to the higher industrialisation and motorisation levels that Latin American countries reached during the period.
[61] Archives Nationales d'Outre-Mer (ANOM), 3TP/78, Afrique Occidentale Française, 1953-1957, République Française, *Afrique Occidentale Française,* 'Plan 1953-1957 d'Équipement Routier de l'AOF', 2.
[62] The remainder five per cent was carried by inland waterways. IBRD, IDA, 'Appraisal of a Fourth Highway Project, Ivory Coast' (Washington D.C., 6 June 1973), 3.
[63] IBRD, IDA, 'Appraisal of a Highway Rehabilitation Project, Nigeria' (Washington D.C., 10 September 1969), 5 (hereinafter: IBRD, 'Appraisal of a Highway Rehabilitation Project, Nigeria').
[64] IBRD, 'Appraisal of a Highway Rehabilitation Project, Nigeria', 5-6.
[65] IBRD, 'Appraisal of a Highway Rehabilitation Project, Nigeria', 6.
[66] IBRD, IDA, 'Appraisal of a Highway Project, Indonesia' (Washington D.C., 3 June 1969), 4 (hereinafter: IBRD, 'Appraisal of a Highway Project, Indonesia, 1969').
[67] IBRD, 'Appraisal of a Highway Project, Indonesia, 1969', 4.
[68] IBRD, 'Appraisal of a Highway Project, Indonesia, 1969', 4.

km carried by train decreased from about 1 billion to 0.6 billion from 1962 to 1967.[69] Although roads were in equally poor conditions in the late 1960s, and unpaved roads formed the majority of the length of each category of road still in 1969, the circulation of motor vehicles was nonetheless possible, if only at speeds below 15 km/h.[70]

However, the railway maintained its place as the main transporter of freight in many colonies and countries during the period – which seems to have been related to state measures to protect railway networks. For instance, the East African Railways (serving Kenya, Uganda and Tanganyika) more than doubled the volume of freight they carried from 1938 to 1953.[71] By 1969, in Kenya, the railway route between the port of Mombasa and the western border with Uganda, along with the subsidiary lines feeding into it (about 1,600 km combined), carried the majority of the country's imports, exports and long-distance bulk traffic.[72] In 1969, the World Bank considered that the state, in its attempt to protect the railways, had excessively regulated and restricted commercial road transport, and that these measures should be relaxed to allow for free competition.[73] In Ghana, in 1969 the railway was the main carrier of the principal export commodities (cocoa, timber, bauxite and manganese ore), which constituted over 90 per cent of its freight.[74] Yet, for other commodities (and for passengers) roads were of 'prime importance', according to the World Bank, and they were the basic transport method serving the area beyond the three main urban areas in the south, which were connected by the railway system.[75]

India's development plans (and in particular industrialisation initiatives) were closely linked to railways and not roads during the 1950s and 1960s. Railway traffic in India grew considerably during the period, as well as public investment in the maintenance, modernisation, and to some extent extension of the railway network. Between 1951-52 and 1955-56, the total volume of freight originated increased by 18 per cent (from 96.6 million tons to 114 million tons) and the number of freight ton miles from 28,966 million to 36,458

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[69] IBRD, 'Appraisal of a Highway Project, Indonesia, 1969', 4.
[70] IBRD, 'Appraisal of a Highway Project, Indonesia, 1969', 8.
[71] Passing from 587 million ton-miles in 1938 to 1,440 ton-miles in 1953. IBRD, 'Appraisal of the East African Railways and Harbours Administration Development Program' (Washington D.C., 25 February 1955), Appendix F.
[72] In 1969, the Eastern African Railways and Harbours Administration amounted almost 5,800 km of railways. IBRD, IDA, 'Appraisal of a Second Highway Project, Kenya' (Washington D.C., 28 May 1968), 2-3.
[73] IBRD, IDA, 'Appraisal of a Second Highway Project, Kenya', 4.
[74] IBRD, IDA, 'Proposal for a Highway Engineering Credit, Ghana' (Washington D.C., 9 June 1969), 2.
[75] These areas were: Accra-Tema, Kumasi and Takoradi-Sekondi. IBRD, IDA, 'Proposal for a Highway Engineering Credit, Ghana', 2.

million.[76] In the following decade, the volume carried by the railway increased from about 87,700 million net ton-km in 1960-61 to 125,000 million net ton-km in 1968-69.[77] Transport investment reflected the prioritisation of railways during the period. Total railway investment was of Rs. 11.2 billion in the Second Five-Year Plan and the Third Five-Year Plan proposed a total investment of Rs. 12.2 billion.[78] In contrast, investment in roads during the Second Plan was expected to be about Rs. 2.7 billion, and the Third Plan allocation was about Rs. 2.5 billion – a sum the World Bank qualified as 'totally inadequate' in 1960.[79] Nevertheless, the Bank provided ten times more funding for railway than for road projects in India during the period. From 1949 to 1969, India received over 600 million USD from the Bank for 13 railway projects, while it only received about 60 million USD for one road project during the same period.[80] Nonetheless, as previously noted, India's road transport and network also experienced significant growth during the period.[81]

In general, the World Bank lent more money for roads than for railways during the period. From 1949 to 1970 inclusive, the World Bank lent over 2,600 million USD for 157 road projects around the world, and about 1,960 million USD for 78 railway projects.[82] In addition, the majority of railway loans were destined for the maintenance and improvement of existing lines – and in great part for the purchase of machinery and other equipment to renovate, maintain, and facilitate the future maintenance of the networks.[83]

The argument for roads over railways was clearly made in the early 1950s by, for instance, the British engineer Sir Kenneth Mitchell. He argued that despite the fact that railways could be more economical for certain traffic over long distances, 'the transport to be provided in at

[76] IBRD, 'Technical Report on the Indian Railways' Five Year Plan, India' (Washington D.C., 1 July 1957), 6.
[77] IBRD, IDA, 'Appraisal of Tenth Railway Project, India' (Washington D.C., 9 September 1969), Table 9.
[78] IBRD, 'India's Five-Year Plan, Report of Bank Mission to India, The Main Report' (Washington D.C., 10 August 1960), 33.
[79] IBRD, 'India's Five-Year Plan', 33-34.
[80] World Bank Projects & Operations Website
http://projects.worldbank.org/search?lang=en&searchTerm=india%20road (30/05/2019).
http://projects.worldbank.org/search?lang=en&searchTerm=india%20railway (30/05/2019).
[81] This was probably related to provincial, rather than national investment.
[82] These figures are not precise, they are meant to give an indication of the magnitudes of funding provided. Some transportation projects contained both rail and road components and are not included in these figures. World Bank Projects Website http://projects.worldbank.org/ (05/06/2019).
[83] See e.g. IBRD, 'Appraisal of the Rehabilitation Program for the Pacific Railroad of Mexico' (Washington D.C., 13 July 1954); IBRD, 'Report on the Development Program of the Nigerian Railway Corporation' (Washington D.C., 18 April 1958); IBRD, 'Report on the Appraisal of the Indian Railway Project' (Washington D.C., 12 August 1949); IBRD, IDA, 'Appraisal of a Second Railway Project, Yugoslavia' (Washington D.C., 30 November 1964).

present under-developed countries will be solely or mainly by road'.[84] Roads offered, in contrast to railways, the 'transport necessary to build up the economy of the backward country or area at the lowest possible cost in the early critical years'.[85] Mitchell had been appointed consulting engineer to the Government of India for Roads in 1930, was wartime Chief Controller of Civil Road Transport in India, and Chairman of a Departmental Committee advising on post-war road development and transport coordination in India from 1945-46), and was considered an authority in the field of road development by the 1940s. Along similar lines, the engineer and British conservative politician F.J. Erroll (who served as Technical Adviser to the South East Asia Command on armoured fighting vehicles during the Second World War, was elected Member of Parliament for Altrincham and Sale in 1945, and later became Minister of Trade and of Power) stated in 1951 that roads were 'the appropriate way to develop virgin territory', writing about transport in African colonies.[86] The reasons he gave were first, that new techniques made road construction quick and cheap (unlike rail construction), second, that roads could be improved and expanded as traffic increased without great increase of capital investment, and third, they could also be easily linked to other roads without the problems posed by the variation in gauges.[87] Erroll also noted that roads required less capital cost because the maintenance and repair of vehicles was in the hands of road hauliers and workshops.[88] Roads were therefore also more suited to respond to strategic needs. As Erroll claimed in 1951:

> for strategic communications, roads are better than railways, because they can be built very quickly and one need not spend much on them. Most modern armies move on lorries rather than by train, and bring their own road transport with them, so that they can always make use of roadways whereas it is not so easy to use railways. The country supplying the troops may have its own gauge: bomb damage on railways takes a long time to repair, whereas a lorry can always drive around the site of the bomb crater and proceed on its way.[89]

Indeed, the Second World War had prompted the construction and use of roads at a large scale, often through virgin and difficult territory, under considerable time pressure for construction (see below).

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[84] Sir Kenneth Mitchell, 'The Logical Stage Development of Roads in Under-Developed Countries', in *Road International*, 3 (1951), 40.
[85] Mitchell, 'The Logical Stage Development', 40.
[86] F. J. Erroll, 'Transport in Africa, A Comprehensive Study of Means of Communication Throughout the Continent', in *Road International*, 3 (1951), 48.
[87] Erroll, 'Transport in Africa', 49.
[88] Erroll, 'Transport in Africa', 50.
[89] Erroll, 'Transport in Africa', 50.

These arguments related to the construction of roads in British colonies, but similar opinions about the advantages of roads were common at the annual meetings of PIARC, in Latin American engineering debates, and amongst World Bank staff in the post-war period. For instance, in 1951, a PIARC Indonesian report stated that 'opening-up' new districts with the construction of standard or narrow gauge railways had been an error in the past, and that roads were a better option for this purpose due to the requirement of low initial investment in comparison with railways:

> Experience has proved that railways require from the outset heavy investment of capital which for the time being is not profitable and which is in danger of getting totally lost if the development of the district does not run as smoothly as anticipated. Construction of highways, on the contrary, can be done on the principle that as many roads as possible are made in the most economical manner. This will be achieved by practicing the utmost restraint in the projection of roads, which are gradually expanded, and in the first place by also making use of the navigable parts of the rivers.[90]

Almost a decade later, one of the technical committee's report at PIARC linked road construction of low trafficked roads and of main roads in 'underdeveloped countries' to a high capitalisation rate policy. According to the delegates (from France, Belgium, Great Britain, Italy, Portugal, and Turkey), in contexts in which insufficient funding was available to build the necessary road infrastructure to respond to the transport demand, 'communities' were 'obliged' to meet only the most urgent needs in order to avoid a 'future catastrophe', even if this meant sacrificing the quality of the works, an increase in maintenance costs, and high operating costs for road users.[91] Therefore, for road engineers at PIARC, roads presented the advantage of being motorable without requiring high quality standards, which means they could demand relatively low initial expenditure, unlike railways.

Latin American road engineers put forward similar arguments. For example, the Colombian engineer Sebastián Ospina B., a fierce promoter of road development (and US-educated), argued in the 1940s and early 1950s that roads were better suited to the country's topography and financial situation, as the mountains that traversed the country made railway construction and operation particularly expensive.[92] Therefore, he concluded, a poor country with a rugged

[90] J.J. Jonker et. al., 'Sections 1 and 2, Question VI Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, with Special Reference to Available Resources and to the Traffic to be Carried, Report by Indonesia', in *Permanent International Association of Road Congresses* (PIARC) (Lisbon, 1951), 6 (hereinafter: Jonker et. al., 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Indonesia').
[91] Committee on Low-Cost Roads, 'Report', in *PIARC* (Rio de Janeiro, 1959), 12.
[92] Sebastián Ospina B., 'Carreteras y Ferrocarriles', in *Anales de Ingeniería de Colombia,* 49 (Jan 1941), 256-258; Sebastián Ospina B., 'Especificaciones Para el Trazado de Nuestras Carreteras', in *Anales de Ingeniería de Colombia,* 54 (Sept-Nov 1945), 1265.

topography like Colombia should build roads, which could be built with lower initial investments and which could be more easily upgraded over time.[93] However, Colombian road engineers were generally not in favour of abandoning existing railways, and most civil engineers agreed on the fact that, in ideal conditions, railways were better suited to carry large volumes over long distances than lorries.[94]

Some of the World Bank staff seems to have shared these opinions about the advantages of roads. In the case of Colombia, the Bank's 1949 mission, directed by Lauchlin Currie, stated that roads:

> can be used efficiently by many types of vehicles for both local and long-haul traffic; they can traverse terrain too difficult for railway construction; and the investment in their construction can be adjusted in considerable measure to the economic utility of the route involved, (whereas) a very high minimum investment is always required for a railroad.[95]

Despite vouching for the extension and modernisation of the road network, this mission also recommended significant investment in railway development, including the construction of a new line, a project the Colombian government decided to undertake (see Chapter 4). Over a decade later, by the mid-1960s, Hendrick J. Van Helden (Chief of the Transportation Division of the Technical Operations department at the World Bank in the 1960s) also identified the requirement of comparatively low capital investments as an advantage of roads. However, he added an important nuance to this premise: road transport usually required less *public* funds than railway transport, for both its construction and operation.[96] In countries with limited availability of foreign currency and a small or emerging industry, this factor was of major importance.[97]

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93 Sebastián Ospina B., 'Carreteras y Ferrocarriles de Montaña en Colombia', in *Anales de Ingeniería de Colombia,* 57 (Feb 1953), 11-45.

94 See 'Observaciones al Trabajo Presentado al Primer Congreso Nacional de Ingeniería por los Ingenieros del Consejo Administrativo de los Ferrocarriles Nacionales', in Ospina, 'Carreteras y Ferrocarriles de Montaña'; Guillermo Camacho, 'En Colombia los Usuarios de las Carreteras No Pagan el Total de los Gastos de Conservación', in *Anales de Ingeniería de Colombia,* 49 (Oct 1941), 779-782; Sebastián Ospina B., 'Modernización de los Ferrocarriles. Locomotoras Diésel-eléctricas', in *Anales de Ingeniería de Colombia*, 57 (July 1953).

95 World Bank, *The Basis of a Development Program for Colombia: Summary* (English), (Washington, D.C., 1950), 32.

96 Emphasis is mine. World Bank, International Bank for Reconstruction and Development, International Development Association, 1654773 – Records of Office of External Affairs (WB IBRD/IDA EXT) – Van Helden, Hendrik J. – Articles and Speeches (1964-1971) – 1v. Draft of Address for the Annual Meeting of the International Road Federation in Tokyo (1964), 12-16 (hereinafter: Van Helden, 'Draft of Address for the Annual Meeting of the IRF in Tokyo, 1964') .

97 Van Helden, 'Draft of Address for the Annual Meeting of the IRF in Tokyo, 1964', 12-13.

The 'low-cost' road: between temporary and permanent

The term 'low-cost road' did not have an explicit definition until the 1950s, but its use was common as early as 1930.[98] By the mid-1950s, the PIARC had created a committee dedicated entirely to the discussion of issues related to economic principles and low-cost methods in 'underdeveloped' areas.[99] In the 1959 meeting, the committee confirmed that the concept of low-cost roads was expected to be fruitful in the future, especially in the face of the new challenges brought about by the rapid changes in road transport trends.[100]

Broadly speaking, a low-cost road was characterised by the use of particular materials and methods to build a motorable road that would remain passable all seasons (if possible), at the lowest possible cost, even if the road was not built up to the best technical standards.[101] Low-cost roads were not necessarily cheap, they prioritised keeping costs to a minimum. There was one main element that differentiated low-cost roads from other types of road construction. Although low-cost roads did not prioritise technical standards, they were designed to allow for future improvements. This was called 'stage construction' or 'upgradeability'.[102] The basic implication of upgradeability was that all the non-urgent elements of the road were initially deferred, but the expectation was that these elements were going to be added to the road structure at some point in the future. In general, engineers considered that while surfaces could always be improved, the alignment or the gradients of the roads were very expensive to correct, and should thus be prioritised.[103] However, determining which elements should be provided from the initial stages and which could wait, as well as anticipating the future timeline of upgrades for any road, were complicated processes, and there was no consensus about how they should be carried out. There was no formula applicable to every situation for the negotiation between lowest possible cost and maximum technical standards. It was considered that 'the highway engineer must select the

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[98] See, e.g., PIARC, 'Proceedings of the Sixth International Road Congress - Part 1', in *PIARC* (Washington D.C., 1930), 1–241.
[99] Committee on Low Cost Roads, 'Report', in *PIARC* (Rio de Janeiro, 1959), 4-5.
[100] Committee on Low Cost Roads, 'Report', in *PIARC* (Rio de Janeiro, 1959), 17.
[101] Anon., 'Section 1, Construction and Maintenance, Question 3 Low-Cost Roads, General Report', in *PIARC* (Istanbul, 1955).
[102] Anon., 'Section 1, Construction and Maintenance, Question 3 Low-Cost Roads, General Report', in *PIARC* (Istanbul, 1955), 11.
[103] R.S. Colquhoun, 'Low-Cost Roads in Undeveloped Countries', *Road International*, 1 (1950), 54.

solution which each case demands, having regard to the materials available and the conditions of climate, soil and traffic, on which he should be accurately informed'.[104]

Even if engineers managed to find a solution taking into account all those variables, they could not predict how conditions would change over time with precision (and indeed traffic growth in the developing world exceeded most predictions during the period), which meant engineers could not define the design life of the road in advance, i.e. they did not know how long roads were going to last before reconstruction or significant improvement was needed. In general, the low-cost roads of the developing world were expected to last half the time as the main roads of developed countries, in great part due to the rapid rates of traffic growth. For the British Road Research Laboratory (RRL), for example, in 1962, roads in 'the developing countries in the tropics' were built to last for about ten years without major reconstruction, in contrast to roads in developed countries, which were designed to respond to demands for the following 20 years.[105] This was related to the rapid growth of traffic in the 'less developed countries'.[106] As the RRL explained, while increases of 15 to 20 per cent per year were common in developing countries, in Great Britain annual increase was of the order of seven per cent.[107] This meant that, twenty years after built, roads in developing countries would have to carry about 15 times more traffic, against only four times in Britain.[108] Another problem, according to the World Bank, was the scarcity of data, which made traffic projections particularly difficult to calculate.[109] By 1969, according to the RRL, the situation had not changed: in developed countries it was considered normal to design roads for the estimated traffic over a period of twenty years, while in most developing countries it was usual to adopt a design life of ten years in the first instance, and assess what the traffic would be over that period for the purposes of initial construction.[110] This was still related to the high

[104] Anon., 'Section 1, Construction and Maintenance, Question 3 Low-Cost Roads, General Report', in *PIARC* (Istanbul, 1955), 3.
[105] NA, DSIR 28/309, Road Research Laboratory (RRL), Road Note, A Guide to the Structural Design of Bituminous-Surfaced Roads in Tropical and Sub-Tropical Countries (1962).
[106] NA, DSIR 28/309, RRL, Road Note, A Guide to the Structural Design of Bituminous-Surfaced Roads in Tropical and Sub-Tropical Countries.
[107] NA, DSIR 28/309, RRL, Road Note, A Guide to the Structural Design of Bituminous-Surfaced Roads in Tropical and Sub-Tropical Countries, 4.
[108] NA, DSIR 28/309, RRL, Road Note, A Guide to the Structural Design of Bituminous-Surfaced Roads in Tropical and Sub-Tropical Countries, 4.
[109] IBRD, *A Guide to Highway Design Standards* (Washington D.C., 1957), in Transportation Research Board (TRB), Transportation Technology Support for Developing Countries, *Compendium 1, Geometric Design Standards for Low-Volume Roads* (Washington, 1978), 7-9. The Bank considered that pavement surfaces themselves were meant to last no more than five to seven years. IBRD, *A Guide to Highway Design Standards* (Washington D.C., 1957), in TRB, Transportation Technology Support for Developing Countries, *Compendium 1, Geometric Design Standards for Low-Volume Roads*, 5, 46.
[110] NA, DSIR AY26/28, RRL, M.P. O'Reilly and R.S. Millard, 'LR279 Roadmaking materials and pavement design in tropical and sub-tropical countries' (1969), 4) Roads with permanent surfaces.

rates of traffic growth, which made it 'uneconomic' to design roads to serve the traffic of the following twenty years, in terms of both layout and strength.[111] Low-cost roads were a quick and relatively inexpensive palliative solution designed to respond to urgent demands usually by running the risk of increased future expenditure.

Although low-cost roads were not exclusive to the developing world, they acquired a particular significance there. While low-cost roads in developed countries usually corresponded to parts of the network of secondary or tertiary importance, in developing countries or colonies they generally played important roles within trunk networks.[112]

The temporary roads of the US Army Corps of Engineers in the Second World War

One very important reference point for the low-cost road were the roads built by the US military during the Second World War. These were rapidly built roads, often using heavy machinery, designed for a short life. The temporary roads of the US Army Corps of Engineers influenced the way low-cost roads were built from then on. Although 'road expedients' (such as the corduroy road) were not common after the war, construction of unpaved, substandard, seasonal roads, using the same machines and low-quality local materials was widespread in the developing world from the late 1940s through the 1960s.[113]

Road construction was one of the essential tasks undertaken by the US Army Corps of Engineers during the Second World War on a huge scale. As the narrator of an official training film of the US Army Service Forces put it: 'While most of our equipment travels first on the high seas, or even by air freight, eventually it must be transported on roads. Roads that feed the combat zone, roads that carry the guns and machines from their factory in Detroit to the men that need it, when they need it'.[114] The mechanisation of works was one of the main strategies adopted by the US Army Corps of Engineers to accelerate construction processes, although this did not entail the disappearance of manual labour (see Chapter 2).

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111 NA, DSIR AY26/28, RRL, M.P. O'Reilly and R.S. Millard, 'LR279 Roadmaking materials and pavement design in tropical and sub-tropical countries', 4) Roads with permanent surfaces.
112 Committee on Low Cost Roads, 'Report', in *PIARC* (Rio de Janeiro, 1959), 9; R.S. Colquhoun, 'Low-Cost Roads in Undeveloped Countries', *Road International*, 1 (1950), 50.
113 Corduroy roads had been used for centuries in many places, but they were extensively used during the Second World War, as they allowed the passage of heavy machinery through swamps or wooded areas and were easily made from a combination of wood and gravel or bush. New ways of building this road were created by the US Army Corps of Engineers. For instance, for desert areas they used rolls of chicken wire covered by a layer of cloths or sandbags, in turn covered by another layer of wire. US Department of War, Army Service Forces, Signal Corps Production, 'Military Roads' Official Training Film (TF5-1193), n.d. https://archive.org/details/gov.dod.dimoc.29327 (14/09/2018).
114 US Department of War, Army Service Forces, Signal Corps Production, 'Military Roads' Official Training Film (TF5-1193).

Although these roads had to bear very heavy traffic and endure constraining environmental conditions, they were mostly unpaved and they were not designed to last long. Figure 1.1 illustrates the unpaved surface and heavy traffic that characterised the Ledo road (alternative route to the Burma road connecting India and China). The finished Ledo road was weather-dependent and regular maintenance works were necessary even during construction, as 'the jungle would start taking over again'.[115] Heavy traffic and raids also significantly increased the need for maintenance works, which often continued during the night.[116] However, the road was not meant to last beyond wartime, and therefore a more sturdy structure or surface was considered superfluous.

Figure 1.1 American lorries on the Ledo Road during World War II

[Picture removed from ethesis version on copyright grounds]

Source: 'US-built Army trucks wind along the side of the mountain over the Ledo supply road now open from India into Burma...', n.d. 208-AA-45L-1. Taken from 'Pictures of African Americans During World War II', at the National Archives and Records Administration (Still Picture Branch) Website. https://www.archives.gov/research/african-americans/ww2-pictures (16/09/2018)

[115] Karl C. Dod, *United States Army in World War II. The Technical Services, The Corps of Engineers: The War Against Japan* (Washington D.C., 1987), 473; Henry Byroade, Interview by Niel M. Johnson (Maryland, 19 September 1988). Transcript available at the website of the Harry S. Truman Presidential Library and Museum: https://trumanlibrary.org/oralhist/byroade.htm (14/09/2018)
[116] Dod, *The Corps of Engineers: The War Against Japan*, 102.

The fact that wartime roads were not made to last long was made explicit in the official history of the US Corps of Engineers for the case of Australia. In 1942, as the American engineers started guiding 'the Australians in the unfamiliar task of building for the American Army', they noted that the Australians were building 'over-elaborate' roads with structures 'better suited for a permanent peacetime highway than for a temporary military supply route'.[117] The Americans insisted construction should 'be held to "bare essentials"' and suggested the deferral of long-term projects.[118] Many Advisory War Council officials agreed and through their control of manpower, materials, and equipment focused the efforts on the projects that would contribute to the war effort (even if supplies and materials had been allocated to other projects before Japan entered the war) and saw that what they called "spit and polish" construction was avoided.[119]

Between cumulative improvements and reconstruction: the evolution of upgradeability

Low-cost roads were not meant to be temporary, only some of their elements were. However, how long should a low-cost road last before significant improvement (as opposed to routine maintenance) and/or reconstruction was needed? And how could road engineers make sure that their roads were built to the (minimum) sufficient standard that allowed them to last that particular amount of time? The decision about which elements were deferred and which were to be built to a permanent status from an early stage was the result of a negotiation between engineers and road authorities and varied greatly between cases. However, some general trends seem to emerge from the PIARC and United Nations Educational Scientific and Cultural Organisation (UNESCO) meetings and publications, as well as from World Bank's staff appraisal reports.

Low-cost roads were meant to be upgradeable: they were designed to facilitate improvements over time that would progressively transform earth tracks into all-weather paved roads – provided the level of traffic justified the necessary upgrades. This logic, also known as stage construction, was already moulding road construction in the interwar period.[120]

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[117] Dod, *The Corps of Engineers: The War Against Japan*, 138.
[118] Dod, *The Corps of Engineers: The War Against Japan*, 138.
[119] Dod, *The Corps of Engineers: The War Against Japan*, 138.
[120] 'A low cost road is one which, having regard to conditions of climate and traffic, has been constructed down to a price rather than up to a standard. It is, however, one which should be so designed, constructed and maintained that it allows for stage construction when improvement in economic conditions permits'. F.H.P. Williams, et. al., 'Section 1 Construction and Maintenance, Question III, Low-Cost Roads, Great Britain', in *PIARC* (Istanbul, 1955), 3 (hereinafter: Williams et. el., 'Construction and Maintenance, Low-Cost Roads, Great Britain, 1955').

From at least the 1930s until approximately the mid-1950s, the concept of upgradeability was connected to an ideal of cumulative improvements. This model implied that each improvement corresponded to an *addition* to the previous one and was supposed to become an integral part of the final stage of the road. Therefore, road engineers aimed to build permanent structures (such as drainage) along the roads' definitive alignment (profile and route) from the early stages of construction, leaving the improvement of characteristics such as width and type of surface to later stages.[121] Discussing the topic of the construction of roads in colonies and 'undeveloped regions' at the 1930 PIARC meeting in Washington D.C., the French, British and American reports presented the methods used to determine road alignments and make them permanent as soon as possible. French engineers advised undertaking a comprehensive survey of the route location before beginning any partial improvements, and their British counterparts highlighted the importance of ensuring the alignment accommodated all mechanically propelled vehicles, as well as draught animals.[122] American engineers explained how their general tendency was to look for direct routes 'on the most permanent and economic location obtainable', but that sometimes low standards were justified if the needs were urgent and funds limited.[123] However, even in these cases, surfaces that were considered expensive were not used on temporary alignments because they anticipated that these would be discarded over time.[124]

In the mid-1950s, the PIARC reports continued to indicate similar approaches to road upgradeability. The General Report on Low Cost Roads at the 1955 congress concluded that one of the primary objectives of new construction was to make roads permanent and eliminate

[121] In 1964 French engineers defined this model as 'the idea that all partial improvement ought to be an integral part of the final stage, for this idea takes with it the need to build the road right form the first stages on the definitive line and profile'. L. Odier, et. al., 'Section 1 Construction and Maintenance of Roads and Runways, Question VI, Particular Problems of Lightly Trafficked Roads, France', in *PIARC* (Rome, 1964), 12 (hereinafter: Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France'). See also Mitchell, 'The Logical Stage Development', 43; R. W. Taylor, 'Sections 1 and 2 Joint Meeting, Question VI, Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, With Special Reference to Available Resources And to The Traffic to be Carried, Nigeria', in *PIARC* (Lisbon, 1951), 14; Jonker et. al., 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Indonesia', 6.
[122] Vicaire and Gubiand, 'Section 1 Construction and Maintenance, Question III, The Construction of Roads in New Countries, Such As Colonies and Undeveloped Regions, France', in *PIARC* (Washington D.C., 1930), 11; Maj. Robert Bruce et. al., 'Section 1 Construction and Maintenance, Question III, The Construction of Roads in New Countries, Such As Colonies and Undeveloped Regions, Great Britain', in *PIARC* (Washington D.C., 1930), 2, 7.
[123] F. R. White, et. al., 'Section 1 Construction and Maintenance, Question III, The Construction of Roads in New Countries, Such As Colonies and Undeveloped Regions, United States of America, in *PIARC* (Washington D.C., 1930), 12 (hereinafter: White et. al., 'The Construction of Roads in New Countries, USA').
[124] White et. al., 'The Construction of Roads in New Countries, USA', 12.

all temporary engineering structures.[125] The French engineers working in French West Africa followed this practice as they included permanent alignment and engineering structures in the first stage of road construction, leaving surface improvements for the second and third stages.[126] In the same year, the British report on low-cost roads noted that final alignment and drainage were a necessary condition to pass from the lower to the higher stages of road construction standards, which for them commonly involved either providing a seal coat of bitumen or grout, or stabilising soil with cement, bitumen or a chemical additive.[127]

However, by the late 1950s road engineers started to move away from the model of cumulative improvements. One important reason was that some low-coast roads were found not to be upgradeable. For instance, the World Bank reported how, despite Iran's high investment on road construction after the Second World War, by 1959 many of the roads built since then required considerable reconstruction or even relocation due to lack of maintenance and low construction standards.[128] The Trans-Iranian Highway (the longest road included in this project) provides an example of the amount of reconstruction that was required. This road ran for more than 1,200 km from the port of Khorroamshahr on the Persian Gulf to the port of Pahlavi on the Caspian Sea (almost parallel to the Trans-Iranian railway built in 1938).[129] The reconstruction of the road cost 87.7 million USD, almost as much as the construction and reconstruction of another 1,200 km of main roads and about 440 km of secondary roads which were included in the same project.[130]

The need for considerable reconstruction of many roads (and, therefore, the limitations of the model of cumulative upgrades) was also noted in countries that had actively participated in the PIARC congresses. In the 1964 meeting, for instance, one of the French reports pointed out that this model was satisfactory only if the roads were built under careful supervision and were continuously maintained.[131] However, the French engineers noted that this was often not the case in 'African developing countries', and they related the bad conditions of the roads

[125] Ulusahin, 'Section 1 Construction and Maintenance, Question III, Low-Cost Roads, General Report', in *PIARC* (Istanbul, 1955), 18.
[126] J. Chauchoy and R. Lantenois, 'Section 1 Construction and Maintenance, Question III, Low-Cost Roads, French West Africa, in *PIARC* (Istanbul, 1955), 28.
[127] Rather than with laterite or a mixture of soils, or just using naturally occurring earth. About these methods see Chapter 2. Williams et. al., 'Construction and Maintenance, Low-Cost Roads, Great Britain, 1955', 14.
[128] IBRD, 'Appraisal of a Road Project, Iran' (Washington D.C., 19 May 1959), 1.
[129] IBRD, 'Appraisal of a Road Project, Iran' (Washington D.C., 19 May 1959), 4.
[130] The high cost of the road reconstruction was linked to the mountainous terrain it crossed. IBRD, 'Appraisal of a Road Project, Iran', 1, 7.
[131] The French engineers referred to this model as 'progressive improvement'. Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France', 12.

(and even their destruction) to the shortage of funds and skilled labour.[132] Discussing the same subject at the congress, their British counterparts stated that poor road conditions in developing countries also resulted from the limited use of cost-benefit studies in the process of determining when, or if, to build permanent alignments.[133] According to them, this frequently led to the construction of roads with standards that they considered either higher or lower than necessary.[134]

This generated a change in the way road engineers thought about road upgradeability. The new definition did not necessarily consider improvements as cumulative; instead, when building a new road, it became acceptable (and even desirable in some cases) to build temporary structures and alignments, even if these had to be abandoned a few years later.[135] In practice, provisional structures and alignments had been common, and now they were the norm.

This definition of upgradeability was ratified by the first manual on road construction and maintenance in developing countries prepared by UNESCO in the mid-1960s. Although the organisation recognised the possibility of building permanent structures, embankments and alignments from the first stage of construction (and leaving surface improvements for the following stages), this option was presented as often unfeasible, unnecessary, and even counterproductive – given that high standard construction could be considered premature for some roads, and therefore an unwelcome diversion of already scarce funds.[136] Instead, *all* road characteristics (including alignment and structures) were expected to evolve over time, and were therefore provisional.[137] The UNESCO text identified three main stages for road construction: 1) motorable tracks, which allowed seasonal motor traffic with the help of some temporary bridges or structures; 2) earth roads, with drainage, embankments and often an improved surface, and which could, over time, reach an all-weather stage with definitive profile and alignment; and 3) a definitive paved road with bitumen or concrete, ensuring continuous circulation.[138] However, unlike the previously accepted practice, the manual noted

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132 Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France', 12.
133 In this report British engineers used 'developing countries' and 'less developed countries of tropical and sub-tropical regions' interchangeably. F.H.P. Williams, et. al., 'Section 1 Construction and Maintenance, Question III, Low-Cost Roads, Great Britain', in *PIARC* (Rome, 1964), 26 (hereinafter: Williams et. al., 'Construction and Maintenance, Low-Cost Roads, Great Britain, 1964').
134 Williams et. al., 'Construction and Maintenance, Low-Cost Roads, Great Britain, 1964', 26.
135 Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France', 12.
136 UNESCO, *Routes Dans les Pays en Voie de Développement: Construction et Entretien, Conditions Économiques et Techniques*, Reference WS/0166.101/APS (1966), 33-34.
137 UNESCO, *Routes Dans les Pays en Voie de Développement*, 28.
138 UNESCO, *Routes Dans les Pays en Voie de Développement*, 29-30.

that the paved stage of the road had, in principle, but *not necessarily*, permanent alignment and structures.[139]

Similarly, in 1964, French engineers at PIARC reported that stage construction had been useful in the former colonies during, and especially after the Second World War, but that current conditions were generating a move away from the idea that each improvement had to be an integral part of the final stage.[140] First, permanent structures required an investment that was not always justified for the level of traffic on every road. Second, the lack of maintenance often destroyed road structures and embankments, even if they had been initially built with high standards. Indeed, these French engineers stated that it was sometimes 'accepted to bituminise a highway on a temporary line, whilst knowing that the alignment will be amended later on'.[141] For them, the benefits of this approach were that investment on earthworks was deferred while maintenance works were made easier and cheaper by paving the surface.[142] This option was therefore particularly attractive in countries in which funds and staff for maintenance works were scarce.[143]

It is difficult to measure the adoption of this new definition. Initially prepared in French, the UNESCO manual was published in both French and English in the late 1960s.[144] These texts were written and edited by important members of the PIARC Committee on Low Cost Roads: the French engineer Lionel Odier (Chief Engineer from Ponts et Chausées, working at the Bureau Central d'Études pour les Équipements d'Outre-Mer), the British engineer Dr R.S. Millard (head of the Tropical Section at the RRL, England, later to become the Deputy-Director of the RRL), the Indian engineer S.R. Mehra (Director of the Central Road Research Institute in New Delhi, India), and the Portuguese engineer Pimentel dos Santos (Director General de Obras Publicas e Communicaçôes, Ministerio de Ultramar).[145] These engineers had been active members of PIARC discussions for decades, and especially in relation to low-cost road building in developing countries and colonies. It is therefore possible to say that

[139] UNESCO, *Routes Dans les Pays en Voie de Développement*, 29-30.
[140] Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France', 11.
[141] Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France', 12.
[142] Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France', 12.
[143] For instance, the practice of paving roads (or giving them a 'black top' surface) even for light traffic in order to reduce vehicle operation costs and maintenance costs in the long term (over 15 or 20 years) was carried out in South Africa in the 1960s. PIARC, 'Proceedings of the IXth International Road Congress – Section 1 Construction and Maintenance of Roads and Runways, Question VI, Committee on Low Cost Roads', in *PIARC* (Rome, 1964), 166.
[144] The version of the manual that we have quoted is preliminary as it contains the comments of the UK Road Research Laboratory on the subject of Maintenance to be included in the English version. The title of the English translation was *Low Cost Roads: Design, Construction and Maintenance* (1971).
[145] Comité des Routes Économiques, 'Rapport', in *PIARC* (Rome, 1964), 5; Comité des Routes Économiques, 'Rapport', in *PIARC* (Tokyo, 1967), 3.

this definition was well known (if not adopted) by the members and correspondent members of the PIARC Committee on Low Cost Roads, which in 1967 included delegates from countries such as Turkey, Poland, Ivory Coast, Mexico, Nigeria, South Africa, and Japan.[146] It is possible that both types of construction of upgradeable roads (cumulative and by reconstruction) were kept as options, and that in practice one or the other was adopted according to each specific case. However, as the networks of the developing countries grew, by the late 1960s and early 1970s most main roads had already been built and therefore new roads were increasingly those that occupied secondary and tertiary roles.[147] Thus, the relatively low level of traffic on these new roads was probably making increasingly attractive the option of building provisional structures and alignments for the upgradeable roads.[148]

Upgradable roads as policies

The move away from the model of the cumulative improvements was accompanied by the realisation that upgradeable roads not only responded to, but also demanded, in and of themselves, a particular road policy. First, stage construction and maintenance were considered inseparable.[149] Indeed, upgradeable roads were considered more vulnerable to wear and tear than roads built up to high standards.[150] Moreover, maintenance itself was also a way of gradually upgrading roads. According to the UNESCO manual, many roads in Africa had been transformed from tracks in that way by the mid-1960s.[151] In fact, around those years in Ivory Coast, for instance, maintenance works and road improvements carried out by the Public Works Department were closely related activities (as they were before independence, Chapter 3). The same teams carried out both types of work, specialising only according to the type of task: reshaping, resurfacing and basic maintenance (such as clearing verges).[152] Second, these roads were designed to be upgraded, and future works had to be more or less substantial depending on the growth of traffic, the quality of maintenance works, and the

[146] Comité des Routes Économiques, 'Rapport', in *PIARC* (Tokyo, 1967), 4.
[147] Van Helden, 'Draft of Address for the Annual Meeting of the IRF in Tokyo, 1964', 15-16.
[148] An example of a country that did not adopt the notion of temporary alignments and structures in the mid-1960s is Portugal. For Portuguese engineers the first stage of road construction was one of: 'shaping up and building earthworks with their definite geometric characteristics' and 'execution of drainage works and protection of embankments against erosion'. Manuel P. Dos Santos, 'Section 1 Construction and Maintenance of Roads and Runways, Question VI, Particular Problems of Lightly Trafficked Roads, Portugal', in *PIARC* (Rome, 1964), 8.
[149] UNESCO, *Routes Dans les Pays en Voie de Développement*, 36.
[150] UNESCO, *Routes Dans les Pays en Voie de Développement*, 35-36.
[151] UNESCO, *Routes Dans les Pays en Voie de Développement*, 36.
[152] J. Maynadie et. al., 'Section 1 Construction and Maintenance of Roads and Runways, Question VI, Particular Problems of Lightly Trafficked Roads, Ivory Coast', in *PIARC* (Rome, 1964), 21-22 (hereinafter: Maynadie et. al., 'Particular Problems of Lightly Trafficked Roads, Ivory Coast').

initial standards of the road. Consequently, upgradeable roads were also tied to a plan of future expenditure.[153]

Although these facts had been well known for decades, road engineers only started referring to them as a policy in the 1960s. At the 1964 PIARC meeting and on the UNESCO manual, engineers stated that the regimes of maintenance and improvements that low-cost roads required were actually road policies that governments needed to understand and follow closely, given that the engineers themselves had little control over future upgrades.[154] The manual pointed out that governments and administrators were, however, often unwilling or unable to respect these policies, resulting in the rapid destruction of roads.[155] For the Portuguese engineer F. Alvares Dos Santos, this meant that low-cost roads were a risk for the engineers' reputation, as they would be the ones held responsible when roads failed.[156]

Although insistent on the need to respect the policy that upgradeable roads demanded, road engineers struggled to explain with precision what this policy consisted of. For instance, British engineers identified three steps for road upgrades in developing countries (un-improved tracks, improved gravel or earth roads and bituminised roads), while engineers in Ivory Coast recognised five of them.[157] Although alignments, surfaces, and whether the road was seasonal or all-weather were generally part of the elements that characterised each stage, there were many others such as the width, the type of drainage and other structures provided, as well as the type of preliminary studies required for the works.[158] Moreover, although the order of road upgrades would usually involve a gradual transformation from an earth track to a bituminised road, engineers did not expect every road to go through all the intermediate stages. Some phases could be avoided if traffic growth, road conditions and funds availability allowed for it (see Chapter 3). In addition, at any one time, a road could have stretches with

[153] UNESCO, *Routes Dans les Pays en Voie de Développement*, 36.
[154] UNESCO, *Routes Dans les Pays en Voie de Développement*, 33.
[155] UNESCO, *Routes Dans les Pays en Voie de Développement*, 33-34.
[156] PIARC, 'Proceedings of the IXth International Road Congress – Section 1 Construction and Maintenance of Roads and Runways, Question VI, Committee on Low Cost Roads', in *PIARC* (Rome, 1964), 164.
[157] The five stages in Ivory Coast were: seasonal roads, improved tracks, earth roads, earth roads with defined alignment and profile, and bituminised roads. Maynadie et. al., 'Particular Problems of Lightly Trafficked Roads, Ivory Coast', 12-15; R.S. Millard et. al., 'Section 1 Construction and Maintenance of Roads and Runways, Question VI, Particular Problems of Lightly Trafficked Roads, Great Britain', in *PIARC* (Rome, 1964), 21.
[158] Main stages also usually contained internal stages – these were even less clearly defined. See e.g. Maynadie et. al., 'Particular Problems of Lightly Trafficked Roads, Ivory Coast', 12-15; UNESCO, *Routes Dans les Pays en Voie de Développement*, 29-30.

characteristics that were different from the rest of the road (and that corresponded to a different stage) if this ensured the homogeneity of circulation conditions.[159]

The timing of improvements was also not clear from the start, as it depended on traffic growth and the quality of maintenance works. The challenges of predicting future traffic demands not only resulted from the lack of data and the rapid and unprecedented traffic growth (as previously mentioned), but also from the inadequacy of measuring traffic with the unit of number of vehicles per day (see Chapter 2).[160] The difficulty of foreseeing traffic development was especially problematic because the evolution of traffic was closely linked to the justification of paving. For example, in the mid-1960s, roads in South Africa bearing above 200 vehicles per day were paved, while in Ivory Coast only roads carrying more than 400 vehicles per day were provided with a bituminous surface.[161] Vehicle operation costs were also an important factor to make this decision (as governments were interested in diminishing transport costs), but research exploring the effects of different road conditions on these charges was only emerging in the 1960s.[162] In addition, maintenance and improvement works were frequently not carried out effectively or opportunely, and it was therefore impossible to predict what the future conditions of any road were going to be at any point in time.

Given how important it was that upgrades were carried out in a timely manner, it is not surprising that the lack of a clear improvement schedule was a significant obstacle for the optimal behaviour of low-cost roads over time.[163] Although not the only factor, the undefined character of low-cost roads' upgrades needs to be taken into account in order to understand why some roads failed only a few years after construction or suffered from constant poor circulation conditions.

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[159] UNESCO, *Routes Dans les Pays en Voie de Développement*, 28.
[160] Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France', 2.
[161] Maynadie et. al., 'Particular Problems of Lightly Trafficked Roads, Ivory Coast', 5, 16; PIARC, 'Proceedings of the XIIth International Road Congress – Section 1 Construction and Maintenance of Roads and Runways, Question VI, Committee on Low Cost Roads', in *PIARC* (Rome, 1964), 166 (hereinafter: PIARC Proceedings, XIIth Congress, Committee on Low Cost Roads).
[162] PIARC Proceedings, XIIth Congress, Committee on Low Cost Roads, 154.
[163] As Dos Santos put it in 1964: 'We could well imagine the most beautiful theoretical schemes for such construction but, if we cannot implement at the proper and right time each phase of these schemes, then the money is wasted'. PIARC Proceedings, XIIth Congress, Committee on Low Cost Roads, 164.

Conclusion

Between 1930 and 1970, the world's road networks expanded, a phenomenon linked to rising motor traffic. The growing road networks of the developing world had to accommodate high proportions of heavy vehicles, and in some cases animal-drawn carts. These road networks were increasingly competing with railways for the movement of goods, even in long distances, especially after the Second World War. Roads also started being preferred for the construction of new routes, mostly because they required lower initial capital investment than railways, but also because they were able to function with low quality standards and were relatively easy to upgrade over time.

The roads of the developing world were built according to a particular logic that prioritised keeping costs to a minimum. These low-cost roads sacrificed quality and increased the risk of high future expenditure on maintenance and reconstruction costs, but offered a quick and relatively inexpensive solution. However, these roads demanded judicious maintenance and timely upgrades, and these were difficult to plan for in advance, especially given the challenges of predicting the evolution of traffic. Therefore, while these roads were meant to last about a decade before needing reconstruction of considerable improvement (half as long as the high-quality roads of the developed world), they often did not last more than a few years. Yet, the provisional character of low-cost roads was not a surprise: it was an essential part of the reason why they were adopted.

Chapter 2 Defying the imagination: the techniques and tools that built the roads of the developing world, 1930-1970

This chapter explores the means used to build, maintain and upgrade low-cost roads. These were based on American methods from the first decades of the century which gained increasing international prestige during and after the Second World War. European colonial powers sought to adapt elements of the American model to suit their own needs and conditions, both in the metropoles and in their overseas territories, for which they also drew upon research they carried out themselves. The main features of this model were the growing mechanisation of road works and the introduction (or increased used in some cases) of the options offered by the emerging fields of soil mechanics and materials laboratory testing.

These changes went along with a growing international road engineering community that adapted and hybridised US approaches with others. The peculiarities of some environmental, traffic, administrative and institutional conditions in the developing world encouraged the creation of innovative practices and artefacts that, despite often being based on foreign tools, equipment and techniques, took new and unique shapes. This chapter suggests that although the transnational exchanges of engineering knowledge were mostly pragmatic in nature, they reflected large-scale economic and political inequalities (such as imperial and informal economic imbalances), as engineers from developed countries had the most resources at their disposal and dominated the spaces of discussion.

How world road construction and maintenance changed has received limited attention from historians.[1] Bruce Seely has examined how elements of US methods were disseminated to and eagerly adopted by Western European countries after the Second World War, mentioning the construction of durable pavements but focusing on the diffusion of traffic engineering (which revolved around automobile use, speed and flow) and aspects related to safety concerns (such as signs and markings).[2] Although Seely noted the importance of the US Army

[1] For a detailed account of technical developments in the late nineteenth and early twentieth century in American road construction and the important role of small contractors see I. B. Holley, *The Highway Revolution, 1895-1925: How the United States Got out of the Mud* (Durham, 2008).

[2] Bruce Seely, '"Push" and "Pull" Factors in Technology Transfer: Moving American-style Highway Engineering to Europe, 1945-1965', in *Comparative Technology Transfer and Society*, 2 (Dec. 2004); Bruce Seely, 'Inventing the American Road: Innovations Shaping the American Freeway', in Divall, Roth (eds.), *From Rail to Road and Back Again? A Century of Transport Competition and Interdependency* (Ashgate, 2015). About the diffusion of traffic engineering in post-war Europe see also Rar Blomkvist, 'Transferring Technology – Shaping Ideology American Traffic Engineering and Commercial Interests in

Corps of Engineers and the Navy's Seabees in the widespread adoption of American earthmoving machinery, the full significance of the war in helping to promote new tools and techniques in Europe and beyond has been largely missed.[3]

The Latin American case has also attracted limited attention.[4] Although the influence of the US has been noted, the material perspective of this phenomenon has remained marginal, thus missing the story of the dynamic adaptation of knowledge and practices that reveals the importance that war and prestige occupied in the choices road engineers made.[5] In other geographical areas, accounts of technical road development are rare. An exception is Katie Valliere Streit's thesis on mobility in Southern Tanzania, in which she recognises the importance of unpaved roads and maintenance, as well as the influential role of the British Road Research Laboratory (RRL) and its research on colonial engineering.[6] However, she did not examine what this research work consisted of, nor did she look into the way research on road materials and construction was conducted in or propagated throughout the British Empire. In addition, although she highlighted the influential role of Asian (and in particular Indian) private enterprises, she did not identify any technical influences apart from British engineering and, crucially, her case study remains an isolated example.

The present chapter is divided into three parts. The first part briefly presents the most important elements of the American road-building model: highly mechanised works, the use of certain road design methods and standards (especially those defined by the American Association of State Highway Officials, AASHO), and materials laboratory testing.[7] This section also explores the way this model circulated, as part of both initiatives to promote it and as a result of phenomena that were not explicitly part of the US public or private agendas. The second part concentrates on the conditions that made road construction in the developing world different from that in developed countries, and especially on the way engineers and

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the Establishment of a Swedish Car Society, 1945-1965', in *Comparative Technology Transfer and Society*, 2 (Dec. 2004), 273-300.

[3] Seely, 'Inventing the American Road'.

[4] See e.g. Melina Piglia, *Autos, Rutas y Turismo: El Automóvil Club Argentino y el Estado* (Buenos Aires, 2014); Michael Bess, 'Routes of Conflict: Building Roads and Shaping the Nation in Mexico, 1941-1952', in *The Journal of Transport History,* 35 (June 1, 2014), 78-96; Simón Uribe, *Frontier Road: Power, History, and the Everyday State in the Colombian Amazon* (Hoboken, NJ, 2017); Álvaro Pachón and Maria Teresa Ramírez, *La Infraestructura de Transporte En Colombia Durante El Siglo XX: Una Descripción Desde El Punto de Vista Económico* (Bogotá, 2006), 277-486.

[5] See e.g. Valeria Gruschetsky, 'Saberes Sin Fronteras. La Vialidad Norteamericana como Modelo de la Dirección Nacional de Vialidad, 1920-1940', in Mariano Ben Plotkin, and Eduardo A. Zimmermann (eds.), *Los Saberes del Estado* (Buenos Aires, 2012), 185-212.

[6] Katie Valliere Streit, 'Beyond Borders: a History of Mobility, Labor, and Imperialism in Southern Tanzania' (Univ. of Houston D.Phil. thesis, 2016).

[7] Created in 1914, the American Association of State Highway Officials (AASHO) changed its name to American Association of State Highway and Transportation Officials (AASHTO) in 1973.

World Bank staff perceived road building in these areas as a distinctive endeavour. The third part examines some examples of ways in which the American model was modified and hybridised to respond to the road-building efforts in diverse contexts. Without attempting to be comprehensive, this section emphasises first the hybridisation that took place in the growing field of laboratory testing, second, the various ways in which mechanisation was adopted (not only for construction but also for the maintenance of unpaved roads) and, finally, the particular ways in which design and construction methods were modified to accommodate high proportions of lorries and animal-drawn vehicles.

This chapter is mostly based on reports and proceedings of the Permanent International Association of Road Congresses (PIARC) during the period, and on the work the RRL undertook for road construction purposes in the British (ex)colonies from the 1930s to the late 1960s. The library of the Highway Research Board (HRB) also supplied significant material, and in particular a publication series product of a project aiming to disseminate amongst developing countries the most useful and relevant information available on road construction in those contexts.[8] Equally valuable were the proceedings of the seminar series entitled 'L'aventure des Laboratoires Régionaux des Ponts et Chaussées', organised by the historian André Guillerme in 2002. This oral history project provided first-hand accounts of French engineers working in materials laboratories during and especially after the Second World War, which, added to the analyses presented by the historians Guillerme, Denis Glasson, and Gerard Brunschwig, amongst others, constituted an important window into the particularities of the French case. Some archival material from the World Bank available online was also useful, and in particular the Staff Appraisal Reports of various road projects and some of the speeches and papers given by World Bank staff in the 1960s.

The American model and its circulation

[8] Although this project took place in the late 1970s, some of the contributions it referenced first appeared in the 1950s and 1960s – offering an idea of the value American road engineering experts attributed to different road research endeavours across the world during the period.

The model: mechanisation

The US was the primary model for the mechanisation of road construction.[9] The mechanisation of road works was identified by road engineers around the world as a central element of the American road-building model. In fact, for the most part, this equipment was invented in the US.[10] The mechanisation of road works had started in the early decades of the twentieth century, as steam rollers and horse-drawn scrapers were slowly being replaced by the new self-propelled agricultural tractors, and other new machines, such as the motor-grader.[11] These earth-moving machines were soon found around the world.[12] One of the most important developments was the motor-grader (along with bulldozers and tractors). Early models of graders (a machine with a long blade used to create a flat surface) were towed behind horses or other equipment, such as steam tractors. The first self-propelled graders appeared in the 1920s, and consisted of a grader fitted to a tractor, and in 1931, the recently founded Caterpillar introduced the first dedicated 'motor-grader' designed as a single unit: the 'Auto-Patrol' (Figure 2.1).[13] Unlike bulldozers, motor-graders were not suited to move large amounts of material or heavy loads; they were designed for projects that required precision and are still used today for finish grading, shaping, ditching, levelling, and creating inclined surfaces, amongst others. From its first appearance in the 1930s, the motor-grader became one of the central components of the plant employed in road construction and maintenance works around the world. The introduction in the 1930s of diesel engines and large air tyres gave the machines more independence, flexibility and power.[14]

Figure 2.1 Caterpillar 'Auto Patrol' motor-grader, ca 1930s

[9] Very little manufacture of road-building machinery was carried out in the developing world. However, some efforts did exist, especially because agricultural tractors could also be employed for road construction and maintenance, see below note 28.

[10] The exception seems to have been the European hydraulic excavator, introduced and refined in the late 1950s and 1960s. The Japanese brand Hitachi also introduced an hydraulic excavator in 1965. William Haycraft, *Yellow Steel: The Story of the Earthmoving Equipment Industry* (Illinois, 1999), xiv-xv.

[11] This chapter focuses on earth-moving machinery but the US also employed machines in other processes from the first decades of the century. As Seely points out, asphalt and concrete spreading machines, rollers, levellers, and lorries, amongst many others, made paving faster and more precise; while aerial photography allowed the preparation of drawings and plans for road programmes faster than ever before. Seely, 'Inventing the American Road', 244.

[12] Earth-moving machinery usually refers to heavy equipment used for shaping, loosening, loading and hauling earth and rock materials for construction. Haycraft, *Yellow Steel,* xv.

[13] http://webuildgeorgia.com/foundations/the-auto-patrol/ (28/02/2019); Seely, 'Inventing the American Road', 244.

[14] Heinz-Herbert Cohrs, *500 Years of Earthmoving* (Wadhurst, 1997),108.

[Picture removed from ethesis version on copyright grounds]

Source: http://webuildgeorgia.com/foundations/the-auto-patrol/ (28/02/2019)

Over a dozen earthmoving machine manufacturers were created in the US in the 1920s, amongst which Caterpillar is probably the most famous.[15] Other companies manufactured attachments for tractors such as blades, scrapers, and front buckets, amongst others (both mounted and towed).[16] Caterpillar, knowing of the importance of this type of product for its own success, started a programme to support these firms by providing them with technical support and engineering drawings, as well as promoting the expansion of their market.

The Second World War was essential for the growth of American heavy machinery manufacturers. According to the first volume of the history of the US Army Corps of Engineers during the Second World War, while the pick and shovel had been the symbol of the engineer soldier in the First World War, the bulldozer replaced them in the Second, as behind it 'stood the full power of construction machinery to move mountains and cut through jungle'.[17] The use of air compressors, bulldozers, tractors, dumper trucks and other machines

[15] Caterpillar was founded in 1925 with the merger of Best and Holt, two American manufacturers of agricultural and logging crawler tractors. This paragraph is based on: Cohrs, *500 Years of Earthmoving*, 66-67, 97.
[16] Letourneau was one of these companies.
[17] Blanche D. Coll, Jean E. Keith, and Herbert H. Rosenthal, *United States Army in World War II. The Technical Services, The Corps of Engineers: Troops and Equipment* (Washington D.C., 1988), 62-63 (hereinafter: Coll et. al., *The Corps of Engineers: Troops and Equipment*).

rose significantly from the early 1940s onwards.[18] In 1942, crawler tractors and other construction plant and equipment represented almost 40 per cent of the value of the engineer supplies.[19] In 1944, at its peak, it represented 53 per cent.[20] Tractors were the most numerous machines: in 1942 almost 10,000 tractors were delivered to the Corps, in 1944 the number rose to 28,785.[21] As an example, the machines used to build airfields around Myitkyina, to serve the Ledo Road in Burma, included: 149 lorries (2.5 tons), 66 tractors, 32 scrapers, 30 motor-graders, 27 rollers, 9 power shovels, and 4 cranes, amongst others.[22] In general, even though standardisation was considered the key to ensuring that enough spare parts of the right kind were available, demand was so high that various models from different manufacturers were purchased. Therefore, for example, different tractors were bought from Allis-Chambers, Caterpillar, Cleveland, and International Harvester as well.[23]

Figure 2.2 Image from the construction of the Ledo Road, 1944

[18] Coll et. al., *The Corps of Engineers: Troops and Equipment*, 34.
[19] Coll et. al., *The Corps of Engineers: Troops and Equipment*, Chart 3, 181.
[20] Coll et. al., *The Corps of Engineers: Troops and Equipment*, Chart 3, 181.
[21] The types of tractors used were usually crawler type, with diesel engines of different sizes going from 91 to 140 drawbar horsepower (Class I), to 36 to 45 drawbar horsepower (Class IV). In contrast, in 1944, only 1,398 bulldozers were delivered. Coll et. al., *The Corps of Engineers: Troops and Equipment*, Table 7 and Table 13, 200, 548.
[22] The plant was most likely used for the construction of the road as well. Karl C. Dod, *United States Army in World War II. The Technical Services, The Corps of Engineers: The War Against Japan* (Washington D.C., 1987), 472 (hereinafter: Dod, *The Corps of Engineers: The War Against Japan*).
[23] Nevertheless, manual labour was employed in great numbers: machines needed skilled operators, supervisors, and contractors, while problems to access spare parts and fuel, as well as the damages caused by raids to the machines complicated the use of machines. The urgency of the works was also a major factor. For instance, works on the Burma Road in 1944 were led by 500 engineers and executed by nearly 12,000 Chinese labourers. The construction of the Ledo road also employed considerable labour. In the Autumn of 1944, for instance, the stretch from Mogaung to Myitkyina (about 65 km long) was built by the 330th General Service Regiment with the help of the 1304th Construction Battalion, and the Chinese 12th Engineer Regiment. Coll et. al., *The Corps of Engineers: Troops and Equipment*, 180; Dod, *The Corps of Engineers: The War Against Japan*, 96, 470-73.

[Picture removed from ethesis version on copyright grounds]

Note: Figures 2.2 and 2.3 were taken from US Department of the Army, Office of the Chief Signal Officer, *The Battle of China, Reel 7*, 4:09 and 4:14 (1944), National Archives Identifier 36072 https://catalog.archives.gov/id/36072 (14/09/2018).

Figure 2.3 Image from the construction of the Ledo Road, 1944

[Picture removed from ethesis version on copyright grounds]

The American earthmoving machinery industry experienced another boom after the war. Already strengthened by wartime activities and the demand generated by the construction of the Interstate Highway System at home, some companies managed to expand their markets in Europe and beyond during the post-war period.[24] For instance, in the 1950s, Caterpillar established two overseas trading companies and two manufacturing bases in Europe (and its largest European base in Belgium in 1960).[25] From 1956 to 1965, Caterpillar's business outside the US usually corresponded to 42 to 46 per cent of its total business.[26] Caterpillar became so iconic that it was often the only brand explicitly mentioned in the lists of machinery needed for road construction projects in the developing world, and most machine manufacturers adopted a shade of yellow for their products.[27]

Although American machine manufacturers dominated the global market for the majority of the twentieth century, some European firms started becoming more competitive in the 1950s and 1960s (even though in general they remained oriented to their national markets).[28] Japan was, however, the country that produced the first companies able to compete with the American giants at an international scale. By the early 1960s, Japanese earthmoving machines were competitive in terms of price and sometimes even quality, especially in developing countries.[29] The Japanese earthmoving industry had emerged by borrowing from western designs, a practice legitimised by the formalisation of license agreements with American and European manufacturers from the mid-1950s to the mid-1960s.[30]

The model: design standards, soil mechanics and materials laboratories

Another element of the American road-building model were road design standards. Geometric design standards defined the road's horizontal alignment (route, in terms of tangents and curves), vertical alignment (profile, such as gradients, camber, etc.), cross section elements (drainage, lane and shoulder widths, etc.), and other features related to the visible features of the road (such as signing, marking and lighting). Geometric design was considered different from structural design, which dealt with materials, carrying capacity,

[24] Haycraft, *Yellow Steel*, 147.
[25] Haycraft, *Yellow Steel*, 160.
[26] Haycraft, *Yellow Steel*, 161.
[27] Caterpillar machines became officially yellow in 1931. Haycraft, *Yellow Steel*, 64; Caterpillar Website, Company History, 1930s https://www.caterpillar.com/en/company/history.html (24/09/2019); Ifor Pugh Wyn and Jan Kanty Wardzala, 'Mechanization of Road Construction in Ghana, 1952-57', in *Conference on Civil Engineering Problems Overseas, 1958* (London, 1958), 85-108; R.W. Taylor, 'Sections 1 and 2 Joint Meeting, Question VI, Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Nigeria', in *PIARC* (Lisbon, 1951), 1-30 (hereinafter: Taylor, 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Nigeria').
[28] Due to the capital needed, the production of heavy machinery was rare in the developing world, although the manufacture of smaller pieces of equipment was more widespread (see Chapter 4). Haycraft, *Yellow Steel*, xiv.
[29] Haycraft, *Yellow Steel*, xv.
[30] Haycraft, *Yellow Steel*, xiv.

pavement thickness, etc.[31] In general, road design standards were fixed by public road authorities (national and subnational) and were continuously revised to reflect the expanding data base of observations and research and to make general design standards fit specific problems.[32] The American Association of State Highway Officials (AASHO) played a major role in this process in the US. Gathering from the varied research and experience of highway departments in different States, the AASHO defined accepted criteria and standards that, once reviewed by the federal Bureau of Public Roads (BPR), became official.[33] Thus, the AASHO defined the design standards of the Interstate Highway System and of primary, secondary and feeder roads – although at the State level each highway department still had the authority of modifying road standards to suit their conditions, needs and demands (except for roads belonging to the Interstate System).[34] In fact, the 1965 edition of the AASHO's *Policy on Geometric Design of Rural Highways* claimed that the association's objective was not to innovate or provide instructions 'to design highways for the future', but rather to report on the common practices and relevant experiences of road engineers over the previous decade, in order to update the previous edition.[35]

In the 1950s and 1960s, American geometric road design attributed a particular importance to speed, capacity and safety.[36] In the mid-1950s, unlike some of their European and in particular British counterparts, American engineers thought of the benefits of roads in terms

[31] AASHO, *A Policy on Geometric Design of Rural Highways* (Washington D.C., 1954), v-x (hereinafter: AASHO, *A Policy on Geometric Design 1954*); AASHO*, A Policy on Design Standards* (Washington D.C., 1956), 6.

[32] Sometimes specific road projects could be assigned different standards than the general national ones, even for the same type of road. Transportation Research Board, Transportation Technology Support for Developing Countries, *Compendium 1*, *Geometric Design Standards for Low-Volume Roads* (Washington, 1978), xvi (hereinafter: TRB, *Compendium 1*).

[33] The American Roadbuilders Association, which represented the highway construction industry, as well as several other organisations, also contributed to and influenced AASHO standards (such as the BPR itself). In particular, the BPR provided assistance for the establishment of a policy for the design of rural roads by making investigations, compiling materials and preparing drafts for the AASHO Committee on Planning and Design Policies to consider. The AASHO had one committee for every topic, and each was composed of representatives of different State Highway Administrations, and often a representative from the BPR. AASHO, *A Policy on Geometric Design 1954*, iii-iv; Daniel J. Minahan, 'The Highway Spot Improvement Program: A Critical Review' (Highway Safety Research Institute, University of Michigan, 1968), 7.

[34] Minahan, 'The Highway Spot Improvement Program', 7-8; AASHO, *A Policy on Design Standards*.

[35] AASHO, *A Policy on Geometric Design of Rural Highways* (Washington D.C., 1965), v-vi (hereinafter: AASHO, *A Policy on Geometric Design of Rural Highways 1965*).

[36] The term road capacity refers to flow, rather than load-bearing (or 'carrying') capacity. AASHO, *A Policy on Geometric Design 1954*, 4; AASHO, *A Policy on Geometric Design of Rural Highways 1965*, 5; National Archives United Kingdom (NA), Department of Scientific and Industrial Research (DSIR), 27-329, RN/2516/WHG, RLM, W.H. Glanville and R.L. Moore, 'America's Approach to the Road Problem, Impressions Gained from a Visit to the USA in late 1954', (June 1955), 4-5 (hereinafter: Glanville and Moore, 'America's Approach to the Road Problem').

of savings in time, wear and tear, petrol and accidents.[37] Prioritising speed had several consequences for road design: curves, gradients, intersections, etc. were thought of in terms of using a design speed 'as high (…) as practicable', which could often increase costs.[38] Geometric design was linked to traffic engineering, a specialty that focused on traffic flow logistics that was born in the US in the early 1930s and which gained academic status at Yale in 1943.[39] In the post-war period, although European engineers also took into account traffic flow, the American approach was different in that it put special emphasis on speed and on guaranteeing the uninterrupted circulation of traffic.[40] As motorisation grew in Europe and cars were reaching increasingly higher speeds, American traffic engineering started being adopted in European countries with important implications on planning and land use at the national and municipal levels.[41]

The American approach to structural design was very influential. Certain American methods of building road surfaces and foundations structures were, for instance, widely adopted around the world (such as 'Marshall Asphalt' and soil stabilisation, see below). However, behind these methods lay a more fundamental and more pervading distinctiveness of the American road engineering model: the development of materials laboratory tests and materials specification standards. In other words, not only how to *use* materials but first and foremost how to *choose* them. As part of an effort to determine the cause of the failure of many roads under heavy traffic during the First World War, and given that the characteristics of every material had an impact on the result of construction procedures, during the interwar period American road research organisations started developing techniques to test materials, as well as specification standards to classify them according to their main properties.[42] With the assistance of the BPR, the AASHO published syntheses, which were frequently updated, of the different tests and materials specifications employed in every State, thus creating standards that would serve as guides for road engineers around the country.[43] Although the

[37] Glanville and Moore, 'America's Approach to the Road Problem', I.
[38] Design speed was defined as the maximum safe speed that could be maintained over a section of road when conditions are so favourable that the design features of the road govern. It was determined out of the physical features of the road influencing vehicle operation. Although related, it was slightly lower than the running speed, i.e. the speed over a section of road (distance divided by running time). AASHO, *A Policy on Geometric Design*, 4, 635.
[39] Blomkvist, 'Transferring Technology', 283.
[40] Blomkvist, 'Transferring Technology', 284-285.
[41] Blomkvist, 'Transferring Technology', 284-285; Seely, ' "Push" and "Pull" Factors in Technology Transfer'.
[42] Bruce Seely, 'The Scientific Mystique in Engineering: Highway Research at the Bureau of Public Roads, 1918-1940', in *Technology and Culture*, 25 (Oct. 1984), 821.
[43] In the 1950s and 1960s, for the case of materials testing and specifications, as well as for road design standards, all the States were represented. It is important to note that the AASHO was not the only organisation that defined standards for road construction. The AASHO standards often corresponded to

standards were intended for an American audience (and made no consideration of materials or environmental conditions that were not found in the US), they were still meant to be modified according to the conditions in different States. In particular, while preparing the specifications of naturally occurring materials (such as rock, soil, gravel, etc.) the AASHO indicated test limits generally considered 'the most liberal that may be safely allowed', expecting that if engineers found 'higher grade' materials they would apply more rigid requirements.[44] What made these testing methods and standard specifications fundamentally different from those used in other countries at the beginning of the twentieth century was their reliance on laboratories. Although some European countries adopted laboratory testing quickly, such as Great Britain, others, like France, remained sceptical of their utility until the Second World War (see below).

The significance of the use of these materials tests and classifications was twofold. First, a more precise knowledge about certain materials properties facilitated the prediction of their behaviour under different conditions and therefore contributed to the control of certain characteristics of the road, such as, for example, its ability to resist heavy rain. Second, the possibility of testing materials along the road sites opened the possibility of using locally available materials (which often helped reduce construction costs considerably).

The study of soils was one of the most revolutionary and influential elements of the American road engineering model. Soil mechanics – the study of soils properties, behaviour and use in civil engineering works – was born in the US in the interwar period with the work of Karl Terzaghi.[45] The understanding of soils properties opened an important possibility: their

procedures already in place in some States (or in use by the BPR), they could be known by a different name, and could also correspond to existing standards from the American Society for Testing Materials (ASTM). However, as we will see below, AASHO publications were widely distributed over the world and were often the way in which many standards were known abroad. In relation to the constant revision of the standards, the introduction of the AASHO standards explicitly welcomed criticisms and provided the name and address of the Committee Secretary to whom suggestions were to be sent. More research is needed to determine the way in which these standards were updated and the extent to which new editions incorporated suggestions. AASHO, *Standard Specifications for Highway Materials and Methods of Sampling and Testing* (Washington D.C., 1955), III (hereinafter: AASHO, *Standard Specifications*).

[44] Unlike the specifications of naturally occurring materials, the characteristics of manufactured materials, such as asphalt or Portland cement, were not considered subject to modification according to local conditions. AASHO, *Standard Specifications*, III.

[45] Terzaghi combined previously existing theories of earth pressure with soil physics, thus founding the field of soil mechanics. He spent an important part of his career in the US (at the Massachusetts Institute of Technology from 1925 to 1929 and Harvard after the war), and his ideas had already started to spread in the US and Germany in the 1930s, although their wide adoption took place after the Second World War (see below). Karl-Eugen Kurrer, *The History of the Theory of Structures: Searching for Equilibrium* (Berlin, 2018), 344; Eduardo Kausel, 'Early History of Soil-Structure Interaction', in *Soil Dynamics and Earthquake Engineering*, Special Issue in honour of Prof. Anestis Veletsos, 30 (September 1, 2010), 824; André Guillerme, 'Le Contexte de la Création des Laboratoires Régionaux des Ponts et Chaussées (1945-

modification.[46] The use of chemical or mechanical treatments to change soil characteristics, a technique called soil stabilisation, allowed the manipulation of certain soil characteristics under particular conditions and, in some cases, it even offered the chance of creating 'new' soils altogether. This technique also emerged in the US in the 1920s and 1930s.[47]

Finally, the US built experimental roads that could be closed to normal traffic for years. The 'AASHO Road Test' is perhaps the most famous full-scale experiment led by the AASHO in the twentieth century. Administered by the HRB and funded by the State Highway agencies, the BPR, the Department of Defense (DoD), and associations such as the Automobile Manufacturers Association and the American Petroleum Institute, the AASHO Road Test consisted of seven miles of two-lane roads (in the form of six loops and a tangent), divided into over 800 sections, each paved with a different combination of surface, base and sub-base thickness (half concrete and half asphalt). After two years of construction, the roads were open to the traffic of heavy vehicles provided by the DoD in 1958, and the behaviour of the roads was monitored for another two years.[48] Some of the conclusions of this experiment became highly influential for the structural design of road pavements around the world, and are still used today.[49] The relative comprehensiveness of American road engineering research and standards facilitated their circulation, especially because of their relative early appearance. That was also the case, for example, of the AASHO's *Policy on Geometric Design of Rural Highways* (1954), known as 'The Blue Book' after the colour of its cover, which was widely distributed in both developed and developing countries and colonies.[50]

1955)', *in L'Aventure des Laboratoires Régionaux des Ponts et Chaussées, Colloque du Cinquantenaire* (28 Nov. 2002), 4.

[46] The studied soil characteristics were: permeability, stiffness and strength. They depend on different factors such as water content and the nature of the soil grains.

[47] Although some forms of soil stabilisation were used in ancient China, India, and the Roman Empire, the modern soil stabilisation of the twentieth century, with the help of materials laboratories and soil mechanics, allowed higher control of the quality of the materials used, guaranteed higher uniformity of materials and thus of the behaviour of the road structure. For a general description of the main types of road pavement see M.G. Lay, *Ways of the World: A History of the World's Roads and the Vehicles That Used Them* (New Brunswick, New Jersey, 1992), 207-251.

[48] Highway Research Board, *The AASHO Road Test, Report 7, Summary Report* (Washington D.C., 1962).

[49] Transport Research Board, Transportation Research Circular E-C118, 'Pavement Lessons Learned from the AASHO Road Test and Performance of the Interstate Highway System' (New York, July 1007), iii; US Department of Transportation, Federal Highway Administration, 'Highway History: AASHO Road Test'. www.fhwa.dot.gov/infrastructure/50aasho.cfm (17/04/2019).

[50] TRB, *Compendium 1*, xvii.

The circulation of the American road engineering model

As Seely has noted, the International Road Federation (IRF) had the explicit objective of promoting (American-style) road development worldwide.[51] Founded in 1948 by officials from firms such as Shell Union Oil, Standard Oil of New Jersey, and the Automobile Manufacturers' Association, amongst others, the IRF encouraged the creation of national road associations abroad, instead of directly lobbying for specific policies.[52] The number of national groups associated to the IRF passed from eight in 1948, to more than seventy in 1963.[53] The IRF presented itself as an apolitical organisation and was listed as a technical adviser to the UN.[54] The IRF was also engaged in moulding the new generations of road engineers through the creation in 1949 of a fellowship programme that funded road engineering students to take post-graduate courses in British and especially American universities.[55] After their academic studies these fellows were invited on a tour which included road projects, administrative offices, research laboratories and manufacturers of road-building equipment, with the objective of providing not only theoretical knowledge but also first-hand observation and, most importantly, contacts: a 'roster of experts' that the fellows could 'consult at some later date'.[56] In its first twenty years, the programme funded 498 engineers from 83 countries, creating, according to Hugh Gillespie (former communications director, and main author of the IRF's institutional history), an 'elite corps of highly-trained road administrators, ministers and directors throughout the world'.[57] In addition, the IRF published extensively; in particular, *Road International*, its bi-annual and then quarterly magazine, played an important role in the circulation of practices related to road transport and construction and, significantly, in the advertisement of American and British road-related industries.

The congresses and trips that took place in the framework of the Pan-American Highway project (which started in the 1920s and continued throughout the century) were also major opportunities for the US to promote its motor-vehicle and road-related industries in Latin America. Although more research is needed to determine the specific role this project played

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[51] Seely, ' "Push" and "Pull" Factors in Technology Transfer', 240.
[52] Seely, ' "Push" and "Pull" Factors in Technology Transfer', 240.
[53] Seely, ' "Push" and "Pull" Factors in Technology Transfer', 240.
[54] Editorial Board, 'Better Living Through Better Roads', *Road International*, 1 (Autumn 1950); Bruce Seely, ' "Push" and "Pull" Factors in Technology Transfer', 240.
[55] In particular Yale, an institution that was considered a centre for road and traffic engineering by the middle of the century. Gijs Mom, 'Roads without Rails: European Highway-Network Building and the Desire for Long-Range Motorized Mobility', in *Technology and Culture*, 46 (2005), 766.
[56] E. A. Hugill Jr., 'International Road Federation Fellowship Program', in Highway Research Record, *Highway Transportation Research, Education and Technology Abroad*, 125 (1966), 52-53.
[57] Hugh Gillespie, *International Road Federation, Fifty Years of Service, 1948-1997* (Dartford, 1997), 32.

in the expansion of the American road engineering model, the Pan-American Highway Congresses provided a space for the international exchange of technical road engineering approaches – a subject for which the US was acquiring growing international recognition, in a context in which the US was gaining increasing economic, political and military power at an international scale.[58]

While in Europe post-war reconstruction contributed to the adoption of American approaches, international funding agencies based in the US, and in particular the World Bank Group, played an important role in the development of road construction and maintenance projects around the world. In the 1950s and 1960s, part of the criteria to obtain a loan from the Bank was its approval of the project's roads' routes, type of surface and geometric design standards (which were meant to be linked to traffic estimations, although data was often considered insufficient for this). The Bank's staff appraisal reports therefore provide elements to compare road projects around the world. In 1967 and 1975, the World Bank carried out two reviews of the staff appraisal reports on the basis of which each road project had been approved from 1960 to 1970, and gave particular attention to the design standards that were adopted. These publications reported that in that decade AASHO road geometric standards had been applied in many countries with few modifications, such as Iraq and Costa Rica, while they seemed to have had no influence on some countries, such as Ecuador.[59] For the IBRD, despite the many differences between national standards, some similarities were visible (e.g. similar median design speeds according to whether the terrain was flat, rolling or

[58] Several historians have established how the Pan-American Highway project was for the US a way to promote its commercial, economic and political interests in Latin America. Although authors such as Valeria Gruschetksy have suggested that the project also exerted a technical influence over road development in the region, the material implications of the project have remained largely marginal issues. The historian Rosa Ficek argued that an effort was made to unify certain planning, design, construction and maintenance aspects of the roads included in the project, as well as to standardise transit regulations, signs and administration. Nevertheless, Ficek did not explain how this process took place, or how these aspects materialised, and more research is needed to understand the specific influence of the Pan-American Highway Congresses in the technical development of Latin American road networks. See Rosa Ficek, 'Imperial Routes, National Networks and Regional Projects in the Pan-American Highway, 1884-1977', in *The Journal of Transport History* 37 (December 1, 2016), 129-154; Rosa Ficek, 'The Pan American Highway: An Ethnography of Latin American Integration' (Univ. of California Santa Cruz D. Phil. thesis, 2014), 46; Rodrigo Booth, 'Automóviles y Carreteras. Movilidad, Modernización y Transformación Territorial en Chile, 1913-1931' (Pontificia Universidad Católica de Chile D. Phil. thesis, 2009); Valeria Gruschetsky, 'La Avenida General Paz, Infraestructuras de Movilidad Urbana, Expertos y Política en Buenos Aires, 1887-1941' (Universidad Torcuato Di Tella D. Phil. thesis, 2017); Eric Rutkow, *The Longest Line on the Map: The United States, the Pan-American Highway, and the Quest to Link the Americas* (New York, 2019).

[59] J. De Weille et. al., 'A Review of Sixty Two Road Project Appraisal Reports: 1960-1966', World Bank Staff Working Paper No. SWP 5 (Washington D.C., 1967), 25-29. The influence of the AASHO was especially evident for the case of bridges, see Frederick W. Cron, 'A Review of Highway Design Practices in Developing Countries' (Washington D.C., 1975), 36. http://documents.worldbank.org/curated/en/577601492798440919/pdf/40967ocr.pdf (05/04/2019).

mountainous), which were seen as the expression of a 'healthy cross-fertilization of engineering thought and practice' that resulted from the activities of international lending and aid organisations and international engineering consultants (as well as from those of the IRF, PIARC and the Pan-American Highway Congresses).[60] In fact, the IBRD prepared material to provide guidance in the definition of road standards and made it available to every country receiving funding from the Bank.[61]

The action of the US Army Corps of Engineers as part of the war effort was a catalyser of the diffusion of the American model of road building. The performance of their sturdy and powerful machines had impressed engineers everywhere they went, even the French acknowledged that American machines 'defied the imagination'.[62] However, the impact of the war was even more direct. The fact that Americans left machinery behind and sold it for very low prices had two major consequences. First, those particular machines continued to be used after the war. Second, and more importantly, the acquisition of spare parts to maintain those machines meant that it was convenient to keep buying the same brand in order to use the same stocks of pieces.[63] American manufacturers made sure to take advantage of this opportunity after the war.

North Africa, for example, became according to the historian André Guillerme a vast landscape for the transfer of civil and military engineering knowledge from the US to France during the war.[64] It was there that French engineers were first exposed to the American materials laboratories in the early 1940s, and this example shaped the way road works were carried out in both the French colonies and the metropole in the second half of the century.[65] In 1944, the French founded a soils and foundations laboratory in Algiers which quickly adopted American standards, techniques, and practices. It was therefore equipped to conduct

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[60] For Frederick Cron, the author of the 1975 review on road standards in the World Bank roads' projects from 1960 to 1970 (and road engineer of the US Federal Highway Administration for over 40 years at the time), the variation in standards was a normal phenomenon that came from the very nature of road standards. For him, standards served as guideposts but did not indicate road design on their own, as the latter depended also on the estimated future traffic, the physical difficulties to overcome, the road maintenance facilities, and available funds. Cron, 'A Review of Highway Design Practices', 26, 39.
[61] TRB, *Compendium 1*, xvii.
[62] Guillerme, 'Laboratoires Régionaux', 8.
[63] For example, some French firms bought Barber-Greene machinery for a low price after the war and kept buying the same brand in order to use the same stocks of detached pieces. Raymond Sauterey et. al., *L'Aventure des Laboratoires Régionaux des Ponts et Chaussées, Les Coopérations entre Entreprises et Laboratoires, Seminaire* (20 juin 2002), 26.
[64] Guillerme, 'Laboratoires Régionaux', 6-8.
[65] Unlike the US and Germany, France did not rely on laboratories for the construction of roads before the war, when the use of manual labour was also privileged as a way of battling unemployment. Although the École des Ponts et Chaussées had a materials laboratory since the nineteenth century, its work was focused on fundamental research and, according to Guillerme, was not made relevant to the war effort. There were very few private laboratories in France at the time. Guillerme, 'Laboratoires Régionaux', 5, 7.

the latest soil and surface analyses, as well as other type of measurements (with mostly American instruments), and was located close to the field.[66] This laboratory was an important tool for the construction and maintenance of Saharan tracks and air runways, such as the construction of the Rabat track in 1944 and, according to Guillerme, it also served as the prototype for the new regional laboratories created in metropolitan France in the early 1950s.[67] In fact, they were equipped to test road-building materials and all had, for instance, an apparatus to measure soil bearing capacity that was modelled on the American one.[68] In their first ten years of existence, these laboratories were crucial factors for the transformation of French road techniques from labour intensive and based on 'traditional' techniques (such as macadam), to relying on scientific measurements, experimentation, and mechanisation.[69] An Algerian division of the Laboratoire Central des Ponts et Chaussées was founded in 1955 tasked with the adaptation of techniques (including American methods and instruments) to the local climate and available materials.[70] French engineers also helped spread American approaches to road engineering to its other African colonies. Laboratories were created in Abidjan and Dakar (although this process was a lot slower than in the metropole), and the mechanisation of works became widespread in some territories (see Chapter 3).

While French engineers seem to have started this process after the war, their British counterparts were already adopting and adapting American road engineering approaches to use in the colonies since at least the 1930s. For instance, British engineers had been experimenting with the principles of soil mechanics and laboratory soil testing in some colonies since the interwar years (and in particular with soil stabilisation in Malaya), and in the 1940s the RRL started receiving and collecting samples of materials from different colonies.[71] The samples included not only naturally occurring soils and aggregates, but also binders and cement, amongst others. They were kept in glass preserve jars (containing about 300 or 400 grams of material) and displayed in a museum available for consultation by

[66] Guillerme, 'Laboratoires Régionaux', 8.
[67] Guillerme, 'Laboratoires Régionaux', 7, 8.
[68] Guillerme, 'Laboratoires Régionaux', 10.
[69] Denis Glasson, 'Les Laboratoires Régionaux des Ponts et Chaussées entre 1950 et 1970: Une Construction Technique, Administrative et Sociale Originale au Sein de l'Administration des Travaux Publics' (École des Hautes Etudes en Sciences Sociales, CNAM, Unpublished Mémoire, 2003), 5.
[70] Gerard Brunschwig, 'Le Développement de la Recherche dans les Laboratoires Régionaux', in *L'Aventure des Laboratoires Régionaux des Ponts et Chaussées, Colloque du Cinquantenaire* (28 Nov. 2002), 22.
[71] J.J. Bryan and Haji Ibrahim, 'Malayan Roads and Some Soils Which Support Them', in *Conference on Civil Engineering Problems in the Colonies* (London, 1948), 137-156; R.J. Bee, 'Some Notes on Laterite – A Soil of Engineering Importance in the Tropics', in *Conference on Civil Engineering Problems in the Colonies* (London, 1948), 191-208; William H. Glanville, 'Engineering Research and the Colonial Engineer Road Research', in *Conference on Civil Engineering Problems in the Colonies* (London, 1950), 54, 65.

engineers and contractors working overseas.[72] By 1963, there were about 1,900 samples from 52 countries, mostly from Africa, and from Nigeria in particular.[73] The RRL continued to study tropical soils and other materials throughout the 1960s, allowing the laboratory to survey and classify a number of soils and, for example, find similarities between tropical clay soils found in Kenya and in North Borneo.[74] The RRL received an increasing number of requests for advice related to road construction from various colonial Public Works Departments and it invested significant effort in attempting to respond to these demands. This work was possible due to the impulse to scientific research that the British empire undertook from the 1940s in an attempt to reinforce its control over the people and resources of its African and Caribbean colonies.[75] The continuation of the RRL research on soils and other road-related issues overseas in the 1960s, after the political independence of many colonies, suggests that the work of the RRL contributed to the continuity of certain imperial dynamics.[76] The fact that the RRL prioritised the provision of services (such as the study of materials for a particular project) instead of strengthening and expanding its training programmes so that overseas public works departments (often severely under-staffed) could benefit from the RRL's expertise in the long- and not only the short-term seems to support this argument.[77]

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[72] The amount of material kept in the museum was only a small sample of the material received (usually in drums). The RRL could also make the materials available for universities and technical colleges for post-graduate research and demonstrations.

[73] NA, DSIR 12/230, RRL, 'The Collection of Overseas Road Materials at the Road Research Laboratory, Laboratory Note No. DN/271/KEC.GAS', January 1963.

[74] NA, DSIR 28-309, LN/44/MJD.DN, M.J. Dumbleton and D. Newill, 'A Study of the Properties of 19 Tropical Clay Soils and the Relation of these Properties with the Mineralogical Constitution of the Soils' (January 1962); NA, DSIR 28-309, BOR.30, Road Research Board, Committee on Overseas Road Research, 'Surveys of Roadmaking Materials Overseas' (March 1962); NA, CM 6-325, Road Research Laboratory, Ministry of Transport and Ministry of Overseas Development, Tropical Section, Tropical Visit Memorandum No. 52, Visit to Nepal (1970), Report to a Visit to the Butwal-Narayanghat Road, 6; RRL, LR 242, M.P. O'Reilly, L.S. Hitch and A.E. Pollard, 'Investigations Into Road-Building Practice in the Tropics, Studies of the Mixing and Compaction of Cement Stabilized Bases on Two Road Construction Schemes in Sierra Leone' (Crowthorne, 1969), https://trl.co.uk/sites/default/files/LR242.pdf (02/03/2019).

[75] See Sabine Clarke, 'Experts, Empire and Development: Fundamental Research for the British Colonies, 1940-1960' (Imperial College London D. Phil thesis, 2006), 231.

[76] By the late 1960s and early 1970s, although the RRL was starting to expand its scope to countries such as Turkey, Nepal and Colombia, overseas research continued to focus on countries such as Kenya, Malaysia, Ghana, Nigeria, Tanzania, and Sierra Leone. RRL, *Annual Report* (London, 1970), 116-118.

[77] The RRL offered some short courses, lectures and volunteering positions at the laboratory to overseas engineers since the early 1950s. However, the RRL could only accommodate three volunteers at any one time, and the fact that volunteering positions were unpaid and no grants were offered to attend the courses in Great Britain significantly limited the number of people that could benefit from them. The requests received by the RRL, many of which were rejected due to lack of resources, suggest that by the mid-1960s many countries still felt they lacked trained engineers and laboratory staff that could test soils and other materials. NA, DSIR, MT 45/750, STAFFING, HEADQUARTERS DIVISIONS. Activities of the Tropical Section of the Road Research Laboratory, April 1964, 3, Appendix C, Requests during last 15 months for Tropical Section staff to work overseas which have had to be refused; NA, DSIR 28/310,

British and French engineers visited the US research laboratories, attended conferences, and studied American road engineering techniques and administration. In 1951, a French mission of thirteen engineers travelled to the US and reported there were many aspects of American road development they thought could be useful to apply in France and its overseas territories such as, for example, the creation of materials laboratories in order to be able to use local materials, soil stabilisation, and the mechanisation of road works.[78] Similarly, after a visit to the US in 1954, the then director of the RRL, William H. Glanville, suggested taking up the way of assessing the state of the road network by comparing capital investment in roads with the gross national product, advocated the replacement of grade intersections by under- or over-passes on new roads, and recommended the RRL conducted its own research into crash injuries so as not to wait for the results of American enquiries.[79]

Ray Millard (named Deputy Director of the RRL in 1965 and highway advisory consultant for the World Bank) claimed in the late 1970s that the adoption of some of these norms and practices had not been based on technical criteria, but on prestige. An example of this was the widespread adoption of Marshall Asphalt. This technique was first created by the Mississippi Highway Department in the late 1930s and refined by the US Corps of Engineers for the construction of airfields during the war.[80] As with other methods of designing asphalt surfaces, the aim was to determine the optimum mixture of component materials (aggregates, asphalt and Portland cement) for a given application. Although not without its shortcomings, this method was adopted in several countries, partly because it could provide a durable, hard-wearing surface that could withstand the stresses induced by heavy wheel loads, and partly because it was simple and relatively inexpensive.[81] Nevertheless, according to Millard, other methods were more appropriate for certain roads in developing countries. For example, Rolled Asphalt (a method developed in Britain based on an American method) produced roads with lower stability and which were more prone to deform under heavy loads, but could generate, nonetheless, roads that were more able to tolerate repeated flexure, a factor that

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Committee on Overseas Road Research: 3rd Meeting, Minutes of the 3rd Meeting, 7) Liaison and Training; RRL, *Annual Report* (London, 1965-66), 134-135; RRL, *Annual Report* (London, 1968), 172; RRL, *Annual Report* (London, 1970), 115.

78 André Rumpler, 'Mission Française d'Ingénieurs Routiers aux Etats Unis, in *Revue Générale des Routes et des Aérodromes*, 252 (Jan. 1953), 25-26.

79 Glanville and Moore, 'America's Approach to the Road Problem'.

80 Marshall Asphalt Method https://www.pavementinteractive.org/reference-desk/design/mix-design/marshall-mix-design/ (05/03/2019)

81 Marshall Asphalt Method, https://www.pavementinteractive.org/reference-desk/design/mix-design/marshall-mix-design/ (05/03/2019); United Kingdom, Ministry of Defence, Defence Estates, 'Marshall Asphalt for Airfields' (2005), available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/33545/spec_132009.pdf (05/03/2019)

gave this method an advantage over Marshall Asphalt for building lightly trafficked roads.[82] Millard lamented that engineers in developing countries did not use this method more often, or other effective alternatives, such as seal coats or surface dressings, which were highly adaptable to different environmental conditions and work regimes (both of the mechanised and labour intensive varieties).[83] He acknowledged that the lack of skilled workers and operators was a significant factor limiting the adoption of these particular alternatives, but he argued that 'the real reason' lay in the acceptance of a 'technological myth' – the assumption that some methods were the most 'advanced', 'civilized' and 'effective'.[84] Until the 1970s, this method was used in western Europe mostly for the construction of airfields because of its ability to withstand increasing weight and pressure, but was usually considered unnecessary for the construction of roads.[85]

Finally, it is worth highlighting that the international network through each engineering knowledge and experience circulated reflected and reproduced several large-scale political and economic inequalities. Not only were certain imperial dynamics reinforced, the very spaces of exchange were dominated by developed countries, as the delegates of the PIARC meetings illustrate it. The developing world was mostly the object of study, rather than a subject participating in the debates, which was in great part a consequence of colonialism.[86] In fact, only from the mid-1960s was there a conscious effort to invite extra-European developing countries to participate in the discussions of the Committee on Low-Cost Roads, which had started convening since 1957.[87] Moreover, since developed countries had the most resources at their disposal in order to undertake road-related research, the developing world depended in many instances on their experiments and conclusions. In addition, as Chapter 5 illustrates it, engineers in developing countries often depended on developed countries'

82 R. Millard, 'The Craft of Highway Engineering', in Transportation Research Record, *Low-Volume Roads: Second International Conference*, 702 (1979), 5.
83 A seal coat is a final layer of bituminous material applied during construction. Surface dressings (also called surface treatment in the US, amongst other names) consist of spraying a film of bitumen or tar on the road surface followed by the application of a layer of stone chippings. In new roads their objective was to provide a durable and waterproof running surface. In maintenance they could have different purposes but mostly they preserve the structural integrity of flexible pavements against traffic and weather. Millard, 'The Craft of Highway Engineering', 6; R. Millard, *Road Building in the Tropics* (London, 1993), 152.
84 Millard, 'The Craft of Highway Engineering', 5.
85 Millard, 'The Craft of Highway Engineering', 4.
86 Although this situation was different for Latin American independent nations, as engineers actively participated in the debates at, for instance, the Pan-American Highway congresses, the US was undoubtedly a dominant figure in these discussions. See also Ficek, 'The Pan American Highway' and Rutkow, *The Longest Line on the Map*.
87 Committee on Low-Cost Roads, 'Report', in *PIARC* (Rio de Janeiro, 1959), 4 (hereinafter: PIARC, 'Committee on Low-Cost Roads Report, 1959'); Comité des Routes Économiques, 'Rapport', in *PIARC* (Tokyo, 1967), 12 (hereinafter: PIARC, 'Comité des Routes Économiques, Rapport, 1967').

publications or events to learn about what their counterparts in other developing countries were doing.

The distinctive challenges of road building in the developing world

The World Bank's perspective

The World Bank offers a good standpoint to examine the particularities of road building in developing countries given that it had access to information from several countries and played an important role in the approval and financing of road projects during the period. The point of view of Hendrick J. Van Helden, Chief of the Transportation Division of the Technical Operations Department at the World Bank in the 1960s, is particularly helpful. In his official papers and speeches of the late 1960s and early 1970s, Van Helden appears at first glance reluctant to draw a stark division between civil engineering in developed and developing countries. Many of the problems that transport infrastructure posed were the same everywhere in the world, he argued, and differed only in degree. In particular, design and construction issues were all similar.[88] For instance, drainage was a common concern in road construction, but it was more so in particularly humid areas. However, Van Helden did recognise that some conditions made construction work in developing countries distinguishable. One of these was the need to work with particularly scarce funds, which influenced works from the planning stage, to the detailed engineering phase. An example of the impact of this limitation was the use of local materials.[89]

Nevertheless, for Van Helden the main distinctiveness of transport projects in developing countries was related to planning. Unlike most developed countries where congestion was generally the main problem, many 'opening-up' roads in the developing world were meant to 'tap hitherto unused resources'.[90] The justification of this kind of project was completely different than that of roads that were meant to alleviate bottlenecks, as the latter was considered obvious, while the former required careful economic analysis and 'a considerable

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88 Hendrik J. Van Helden, 'Civil Engineering and Changing Transportation Concepts in Developing Countries', in *Conference of Civil Engineering Problems Overseas, Institution of Civil Engineers* (London, 1971), 3.

89 See also World Bank, International Bank for Reconstruction and Development, 1654773 – Records of Office of External Affairs (WB IBRD/IDA EXT) – Van Helden, Hendrik J. – Articles and Speeches (1964-1971) – 1v. 'The Role of the Civil Engineer in Development Planning Overseas', *Presentation at the Institution of Civil Engineers* (London, July 1968), 9-10 (hereinafter: Van Helden, 'The Role of the Civil Engineer').

90 This paragraph is based on: Van Helden, 'The Role of the Civil Engineer', 8-10.

amount of judgement and crystal ball gazing', in his words. In fact, according to him, road planning in developing countries would benefit from additional training from the civil engineers so that they were able to consider the economic and financial implications of their products, as well as have a better understanding of the feasibility of the projects. Moreover, an added complication in transport planning in developing countries was the scarcity of certain type of data (such as labour and equipment outputs). This made it difficult to make estimations about traffic growth and the speed and cost of construction works, which, added to the few opportunities engineers had of comparing unit prices with similar projects in the same country, could easily result in what he considered poorly designed projects.

Another major problem was the lack of management and organisational experience. According to Van Helden, developing countries often drowned in reports but lacked the knowledge of how to put their recommendations into place, which led him to claim that what these countries needed were 'doers' rather than new studies.[91] This did not necessarily mean there was a shortage of engineers. In fact, an element that differentiated roads from other infrastructure projects in developing countries was the availability of specialised local expertise.[92] During the 1960s the number of road engineers rose (and in particular those who had been educated in developed countries), and with few exceptions most countries had some form of roads department, as road construction and maintenance were continuous activities everywhere. Nevertheless, despite being competent and knowledgeable, many of these new professionals often lacked vital experience in their fields.

Apart from these general trends, Van Helden also identified two broad geographical areas with characteristic problems related to population density and type of traffic. First, in Latin America and Africa population densities were generally low (especially away from the coasts), and there were long distances between population centres. According to him, in these regions the major problem encountered in road construction was to find a compromise between cost and design standards.[93] Second, in Asia, with high population densities and large volumes of animal and human traffic, especially in urban areas, the problems usually encountered corresponded to the quality and capacity of the existing roads, railways, and water transport facilities – in rural areas the problems were likely to be similar to those of the other regions but he was not specific in his description. Interestingly, Van Helden appears to

[91] This paragraph is based on: Van Helden, 'The Role of the Civil Engineer', 10-11.
[92] According to Van Helden, these countries could rarely afford to use their relatively limited number of engineers to keep a permanent staff working on projects he called 'occasional', such as dams or ports.
[93] This paragraph is based on: Van Helden, 'Civil Engineering and Changing Transportation Concepts', 3.

give limited importance to the impact that traffic and environmental conditions had on the design and construction processes of civil engineering projects.

The engineers' perspective: the case of the RRL

From the early 1930s, the RRL (then known as the 'Road Experimental Station') was providing advice to colonial public works departments about road construction.[94] In relation to the African colonies in particular, the engineer Harry W.W. Pollitt warned in 1952, as the Liaison Officer of the RRL, that the undergoing spurt in colonial road development was being carried out without essential information related to transport costs, traffic growth, local materials specifications and location, and the most appropriate road structure techniques for the local conditions (including bituminous carpets and soil stabilisation).[95] It was in fact considered that although established road construction techniques and methods to test and classify materials were (more or less) applicable in the colonies, adaptation was necessary to respond to local traffic demands, and reflect the differences in climate, topography and materials characteristics – and for this adaptation to happen, it was first necessary to find out what these characteristics were.

With these objectives in mind, visits from the RRL staff to colonial Public Works Departments started as early as 1946 and, nine years later, a Colonial Section was formed within the RRL, fully dedicated to the study of road-making materials and problems in the colonies.[96] In 1959, the Section was renamed 'Tropical', deigned more appropriate given the 'changing world situation', and also thought to be in accordance with the climate in these territories as they were located in tropical or subtropical areas.[97] Despite this change in name, the research priorities of the RRL for overseas research remained largely the same throughout the 1950s and 1960s, as did the geographical scope of its work.[98]

[94] Originally part of the Ministry of Transport, three years after its creation, in 1933, the laboratory was transferred to the Department of Scientific and Industrial Research (DSIR) and renamed RRL. George Charlesworth, *A History of the Transport and Road Research Laboratory 1933-1983* (Aldershot, 1987).
[95] A bituminous carpet (or 'surfacing') is a technique to build road surfaces that consists of a mixture of aggregates coated with bitumen. H.W.W. Pollitt, 'The Need for Colonial Road Research', in *Conference on Civil Engineering Problems in the Colonies, Institution of Civil Engineers* (London, 1952), 6-27.
[96] This Section was financed with Colonial Development and Welfare funds, as well as with the contributions of some colonial governments to both the central organisation of the RRL and to the cost of experimental work done in their countries. Glanville, 'Engineering Research and the Colonial Engineer', 60; NA, DSIR, MT 45/750, STAFFING, HEADQUARTERS DIVISIONS. Activities of the Tropical Section of the Road Research Laboratory, April 1964, 1.
[97] From 1963 the Section started being financed by the Department of Technical Cooperation. NA, DSIR, MT 45/750, STAFFING, HEADQUARTERS DIVISIONS. Activities of the Tropical Section of the Road Research Laboratory, April 1964, 1.
[98] For instance, in 1966, out of the six countries that received staff from the Tropical Section (in the framework of an official visit or a temporary secondment), five were former colonies, and the remaining

Ray Millard (who we noted above as a critic of the Marshall Asphalt), was a prolific writer and several of the articles and books he published in the 1960s and 1970s were more or less explicitly about road building in ‘the tropics’.[99] Millard identified various factors that made of road building in the tropical and subtropical areas a distinctive endeavour. These differences were mostly related to climate and materials characteristics (especially soils). Variation in temperature, local materials, and rain all had a major effect on the design of roads, on the feasibility of different road construction and maintenance processes, and on the performance and durability of road pavements under traffic.[100]

American methods were sometimes more easily applicable than British ones in the colonies and former colonies. For instance, although British engineers had significant experience with the use of crushed stone by the middle of the twentieth century, quarries were difficult to find in most African colonies, and since the transport of rock was extremely expensive, engineers preferred to use other methods (such as soil stabilisation).[101] The RRL considered that in the field of low-cost roads, Americans were ‘pre-eminent in publishing information’, much of which was ‘of interest to colonial engineers’, and in particular the materials tests necessary for soil stabilisation.[102]

However, some of the factors that Millard identified as distinctive of the tropics were not related to the natural environment. One of these factors was the inability to enforce traffic regulations, which resulted in an amount of overloading that was highly damaging for the road surfaces.[103] Millard presented the example of some parts of the Nairobi-Mombasa road in Kenya that were rebuilt in the 1960s according to the country’s regulations on vehicle weight and axle loading, and following traffic growth estimations for the following fifteen years, which should have given the new stretches a design life of at least fifteen years. However, only four years after completion the pavements were showing signs of distress, after which deterioration was rapid, and complete reconstruction of the upper layers of the

country was Hong-Kong. By the late 1960s and early 1970s, although the RRL was starting to expand its scope to countries such as Turkey, Nepal and Colombia, overseas research continued to focus on countries such as Kenya, Malaysia, Ghana, Nigeria, Tanzania, and Sierra Leone. NA, DSIR, MT 45/750, STAFFING, HEADQUARTERS DIVISIONS. Activities of the Tropical Section of the Road Research Laboratory, April 1964, Appendix C, Tropical Section Staff Overseas; Institution of Civil Engineers London, ‘The Report of the Road Research Board with the Report of the Director of Road Research, 1965-66’ (London, 1967), 124; RRL, *Annual Report* (London, 1970), 116-118.

[99] See e.g. R. Millard, ‘Road Building in the Tropics’, in *Journal of Applied Chemistry*, 12 (August 1962); Millard, *Road Building in the Tropics*.

[100] Millard, *Road Building in the Tropics*, 1.

[101] NA, DSIR 27/343, RN/2811/FHP Williams, F.H.P. Williams, ‘Notes on a Visit to Gambia, Gold Coast and Sierra Leone’ (Oct. 1956), 10-11.

[102] Pollitt, ‘The Need for Colonial Road Research’, 22.

[103] Millard, ‘Road Building in the Tropics’, 342.

pavements became necessary. A census of vehicle loading revealed that several lorries had a weight 60 per cent higher than that permitted in the regulations, and for Millard this was proof that overloading was the main cause of the 'early demise of the pavements', a story he qualified as 'familiar'.[104] Another factor was the presence of certain vehicles, such as animal-drawn carts and 'mammy wagons' (i.e. light lorries equipped with wooden benches and carrying up to 40 passengers and their baggage which were found in West Africa since at least the early 1960s).[105]

In 1993, discussing longstanding issues of road development in the tropics, Millard not only identified the lack of management experience as a distinctive characteristic (as Van Helden did), he also emphasised the link between management problems and lack of maintenance. Millard criticised the focus of financial assistance on capital investment works, as for him the assumption that countries would be able to fund and undertake the necessary maintenance of the new roads on their own had been proven wrong. Governments continued to struggle to raise the necessary funds and administer maintenance in a timely and efficient manner, partly because of a certain bias in favour of construction, but also in great part because the lack of regular maintenance often meant that roads started needing major reconstruction faster than they would have had otherwise.[106]

The solutions: adaptation, hybridisation, innovation

Materials laboratories and use of local materials

According to the RRL, by the early 1960s testing laboratories existed in the government departments concerned with road building in almost every country.[107] In addition, by 1970 (if not before), the creation of small testing laboratories on road work sites (known as mobile laboratories) had become standard practice.[108] The spread of materials laboratories was accompanied by the expansion of the use, adaptation and hybridisation of several materials tests and classifications that were originally created in the US. The case of materials

[104] Millard, *Road Building in the Tropics*, 6.
[105] Millard, 'Road Building in the Tropics', 342.
[106] Millard, *Road Building in the Tropics*, 4.
[107] NA, DSIR 28-309, Road Research Board, Committee on Overseas Road Research, Report of the Tropical Section of the Road Research Laboratory for the Period 1st of July, 1961 – 30th June, 1962, 3.
[108] NA, CM 6-325, Road Research Laboratory, Ministry of Transport and Ministry of Overseas Development, Tropical Section, Tropical Visit Memorandum No. 52, Visit to Nepal (1970), Report to a Visit to the Butwal-Narayanghat Road, 6.

classifications illustrates this process. In particular, the soil classification system created by Arthur Casagrande in the US in the late 1940s was used by British engineers, who extended it, creating a considerable number of sub-groups. This new classification system provided valuable information at the survey stage of road projects as it indicated possible design structures for a particular route.[109] A simplified version of the Casagrande classification was created in the US by the AASHO, which did not classify soils by type (e.g. sands, clays), but only divided them into seven major groups, with the aim of simplifying the way to determine if a soil was suitable for a sub-grade or not.[110] Different countries used and modified these classification systems. For instance, in 1959, Portugal used and modified both the AASHO and the British Standard (BS) classification systems to identify and classify its soils and those of its colonies. The changes carried out on the systems were minor, but they were significant because they illustrate how the gradual emergence of national standards took place all over the world.[111] By the late twentieth century, national standards had been created in many countries, often as the result of the adaptation to local conditions of American and sometimes British standards (which could be, themselves, based on American standards as we have seen).[112]

Test methods created in the US were also widely adopted and modified. A good example of this is the California Bearing Ratio (CBR) test, created by the then called California Division of Highways in 1929, and which became the most widely known method to test the load-bearing capacity of soils.[113] The test measured the force generated between a cylindrical metal plunger and a sample of soil or other material at particular intervals of penetration (up to a penetration of 7.5 millimetres). The CBR value was an indicator of the support a soil foundation would give to a pavement structure, as well as of the strength of gravel sub-bases and bases. In an attempt to recreate the worst possible moisture conditions that could occur in the field, the samples were soaked in water for four days before being tested.[114] This information was used in two main ways: first, to determine if a soil stabilisation treatment was necessary and possible (and to establish what type), and second, to help design resistant

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[109] Millard, *Road Building in the Tropics*, 12-13.
[110] Michael Carter and Stephen P. Bentley, *Soil Properties and Their Correlations* (Chichester, West Sussex, 2016), Appendix A, Soil Classification Systems, 194.
[111] No details were provided about the modifications carried out in the PIARC report: Ulpio Nascimiento et. al., 'Section I. Design, Construction and Maintenance of Roads and Runways, Question 1, A. Base and Sub-Base Courses, B. General Questions, Portugal', in *PIARC* (Rio de Janeiro, 1959), 5 (hereinafter: Nascimiento et. al., 'Design, Construction and Maintenance of Roads and Runways, Portugal').
[112] Millard, *Road Building in the Tropics*, 13.
[113] Guillerme, 'Laboratoires Régionaux', 4; Colin A. Franco and K. Wayne Lee, 'An Improved California Bearing Ratio Test Procedure', in Transportation Research Record No. 1119 (1987), 91. http://onlinepubs.trb.org/Onlinepubs/trr/1987/1119/1119-011.pdf (22/02/2019)
[114] Millard, *Road Building in the Tropics*, 29.

road structures, especially flexible pavements. Countries as varied as Colombia, India, Mexico, Morocco and Australia had adopted this test by the 1950s and 1960s.[115] The method had also been used in British and Portuguese colonies since the early 1950s.[116] British engineers had chosen the CBR test because a similar British method measured the resistance of soils to frost damage, a measure that was unnecessary in most colonies.[117] By the early 1970s, the RRL still recommended the CBR technique to design the thickness of lightly trafficked pavements in the tropics and sub-tropics.[118] However, British engineers also created a modified version of the CBR method that gave less emphasis to the soaking of samples (although the four-day soaking procedure was also included as an option).[119]

Some methods were used differently in the developing world, such as soil stabilisation. For instance, whereas in Britain this technique was used to *maintain* the dry strength of the soils in the presence of water and frost, in Africa stabilisation was 'a way of *producing* a *new and different* material of higher strength'.[120] Many experiments were carried out under the direction of RRL staff for this purpose. For example, in 1958, with funds from the Kenya Road Authority and the Materials Branch of the Ministry of Public Works, experimental stretches were built with commonly found clayey soils, which were considered to 'lie outside the range of soils normally accepted elsewhere' as suitable for soil stabilisation.[121] After being mixed in place with hydrated lime, Portland cement or aniline-furfural dye, these soils became usable, and the resulting surface was able to successfully carry about 250 vehicles per day in its first two years of service.[122] The RRL conducted similar research in other colonies and former colonies.

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[115] Pierre Mathis, 'Sections 1 and 2 Joint Meeting, Question VI, Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, With Special Reference to Available Resources And to The Traffic to be Carried, Morocco', in *PIARC* (Lisbon, 1951), 6; S.N. Sinha, 'Section 1 Construction and Maintenance of Roads and Runways, Question I, Design and Construction of Earthworks, India', in *PIARC* (Rome, 1964), 9; J.J.G. Punch and F. West, 'Section 1 Construction and Maintenance, Question III, Low-Cost Roads, Australia, in *PIARC* (Istanbul, 1955), 4; Ministerio de Obras Públicas de Colombia, *Normas de Diseños y Especificaciones de Materiales para Carreteras* (Bogotá, 1965), D120-2; J. Durán Romano, 'Question II Flexible Pavements, Mexico', in *PIARC* (Prague, 1971), 5.

[116] See Eduardo de Arantes E Oliveira et. al., 'Section 1, Road Construction and Maintenance, Question II, Portugal', in *PIARC* (Lisbon, 1951), 4; Nascimiento et. al., 'Design, Construction and Maintenance of Roads and Runways, Portugal', 6-12, 28; Pollitt, 'The Need for Colonial Road Research', 11.

[117] NA, DSIR 27/343, RN/2811/FHP Williams, F.H.P. Williams, 'Notes on a Visit to Gambia, Gold Coast and Sierra Leone' (Oct. 1956), 10-11.

[118] The method was recommended for traffic of up to 1,500 goods vehicles a day. R.S. Millard, 'Question VII Lightly Trafficked Roads, Great Britain', in *PIARC* (Prague, 1971), 12.

[119] Millard, *Road Building in the Tropics*, 29.

[120] The emphasis is mine. Millard, 'Road Building in the Tropics', 349.

[121] NA, DSIR 28-309, Road Research Laboratory, Overseas Bulletin No. 13, An Experimental Stabilized-Soil Road, Makuyu, Kenya (1961), 25.

[122] NA, DSIR 28-309, Road Research Laboratory, Overseas Bulletin No. 13, An Experimental Stabilized-Soil Road, Makuyu, Kenya (1961), 25.

The application of American methods was sometimes wasteful and counterproductive. For instance, in 1959, Indian engineers found that the employment of the CBR test, the most widely used method in the country to calculate the bearing capacity of soils, was resulting in 'oversafe' pavements.[123] Outside areas which were either water-logged or were prone to continuous flooding for long durations, the sub-grade did not saturate completely, such that CBR values pointed to pavements thicknesses that were higher than what was actually needed.[124] In response, a large-scale research project was launched to determine the moisture content of sub-grades after construction around the country and to study the way it affected the structural stability of pavements.[125] In 1952, the RRL engineer Pollitt noted that the CBR could also produce incomplete results because no account was taken of traffic volume or intensity.[126] Millard argued that in some arid areas the CBR was unhelpful, but according to him, even in the late 1970s, engineers in Africa 'solemnly' soaked compacted samples of soils for four days, yielding misleading results for much of the continent.[127]

Engineers often experimented and compared different methods. For instance, in India, the engineer S. Sinha reported at PIARC that by the mid-1960s there was no consensus about which method of soil compaction was better suited for the local conditions.[128] The BS, the AASHO or the 'Modified AASHO' were at the time the most commonly used laboratory tests to determine the degree of compaction and moisture content needed for the soil to achieve its highest dry density. They consisted of compacting soil of a particular moisture content into a cylindrical mould using a compactive effort of a certain magnitude.[129] The process was then repeated with different moisture contents. These three tests employed the same type of mould (called 'Proctor', after the American engineer who first invented the method), and varied mostly in the compactive effort exerted.[130] Sinha explained that 'none of the methods could be deemed to be perfect by themselves alone either in their approach or application' and

[123] Anon. 'Section I. Design, Construction and Maintenance of Roads and Runways, Question 1, A. Base and Sub-Base Courses, B. General Questions, India', in *PIARC* (Rio de Janeiro, 1959), 2 (hereinafter: Anon., 'Base and Sub-Base Courses, India').
[124] Anon., 'Base and Sub-Base Courses, India', 2.
[125] Anon., 'Base and Sub-Base Courses, India', 2-3.
[126] Pollitt, 'The Need for Colonial Road Research', 11.
[127] R. Millard, 'The Craft of Highway Engineering', in Transportation Research Record, *Low-Volume Roads: Second International Conference*, 702 (1979), 2.
[128] S. N. Sinha, 'Section I. Design, Construction and Maintenance of Roads and Runways, Question 1, Design and Construction of Earthworks, India', in *PIARC* (Rome, 1964), 7 (hereinafter: Sinha, 'Design and Construction of Earthworks, India').
[129] Compactive effort is the total energy, expressed as kilo-Newton metres per cubic metre used to compact a specimen. Definition by the Texas Department of Transportation Glossary. https://definedterm.com/compactive_effort/173374 (17/04/2019)
[130] Sinha, 'Design and Construction of Earthworks, India', 7-8.

therefore recommended to choose between methods according to specific needs.[131] In addition, even when a particular method was chosen, it was open to modifications. For example, when Portuguese engineers carried out the AASHO Proctor test in the early 1950s (both in the colonies and in the metropole), they made an important change: samples were to be divided into several portions so that each soil was tested only once, as they had found that successive compactions of a sample could interfere with the results.[132]

Mechanisation of construction and maintenance

In 1955, the British report on low-cost roads at PIARC stated that the most important developments in 'under-developed' areas of the Commonwealth since 1950 had been the increased use and improved efficiency of machines.[133] It became possible, for instance, to have no manual labour involved in earthworks, other than machine operators, their assistants, surveyors and the supervisory staff.[134] Mechanisation offered significant benefits. First, generally speaking, machines were considered to improve the quality of the works.[135] In particular, mechanised paving was portrayed as producing smoother and stronger surfaces than manual methods.[136] Second, machines required a shorter time than workers to generate good results. Indeed, sometimes machines did not necessarily make works less expensive, or improve their quality, but just accelerated their speed.[137] For instance, in Nigeria in 1951, the main advantage of mechanical excavation the saving of time, not money.[138] However, engineers foresaw that, over time, experience gained with bulldozers and scrapers would increase the output of the mechanised works.[139]

Taking full advantage of machines depended on how well these were adapted to the various work and environmental conditions. Sometimes machines did not work well in certain

[131] Sinha, 'Design and Construction of Earthworks, India', 8-9.
[132] Eduardo de Arantes E Oliveira et. al., 'Section 1, Road Construction and Maintenance, Question II, Portugal', in *PIARC* (Lisbon, 1951), 18.
[133] F.H.P. Williams et. al., 'Section 1 Construction and Maintenance, Question III, Low-Cost Roads, Great Britain', in *PIARC* (Istanbul, 1955), 15.
[134] E.R. Rowbotham, 'The Design and Construction of the Humming Bird Highway', in *Conference on Civil Engineering Problems in the Colonies, Institution of Civil Engineers* (London, 1954), 50.
[135] Ulusahin, 'Section 1 Construction and Maintenance, Question III, Low-Cost Roads, General Report', in *PIARC* (Istanbul, 1955), 9.
[136] International Development Association, 'Appraisal of a Road Project for India' (Washington D.C., June 1961), 8 (hereinafter: IDA, 'Appraisal of a Road Project for India').
[137] Although this was a common argument amongst engineers, I could not find an explicit comparison that would prove it.
[138] The cost of both manual and mechanical earthworks was the same, varying only according to the location. Taylor, 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Nigeria', 6.
[139] Taylor, 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Nigeria', 27.

contexts. In the Himalayas in the late 1960s and early 1970s, for example, roads over 400 km-long could run for 90 per cent of their lengths over heights exceeding 3,000 metres above mean sea level (mamsl) and reaching 5,300 mamsl.[140] Combined with temperature, wind velocity, and snowfall and rainfall, these altitudes diminished the efficiency of both labourers and machines. While workers suffered from dizziness, sleeplessness, pulmonary oedema, and frost bites, amongst other conditions, the power loss of the machines was estimated at 3 to 4 per cent for every 300 m of rise in altitude, becoming acute beyond 3,000 mamsl. Different measures were taken to overcome these obstacles such as using winter grade and sub-zero diesel oils, resetting of fuel injection pumps, and introducing turbo-chargers, amongst many others. The high altitude and its corresponding reduction of machine efficiency even precluded the employment of imported snow clearing machinery. This machinery was not considered suitable to deal with the requirements of clearing snow mixed with earth and boulders at considerable depths with reduced power. Bulldozers were used instead, with satisfactory results.

In another example, in Nigeria in the early 1950s, D6 Caterpillar tractors were used for earth moving, even though D8 tractors were accessible and more efficient, because the weight of the latter kept them from reaching certain construction sites.[141] In fact, the transport of machinery to isolated sites, and the need to build structures, such as bridges, to guarantee their safe and timely delivery, was a frequent challenge in the developing world.[142] Dismantling equipment into smaller components easier to transport was not unheard of, even in the early 1970s.[143] Modifying the plant was also a frequent solution employed to ensure the continued used of machines. At the 1964 Conference on Civil Engineering Problems Overseas (Institution of Civil Engineers, London), William Joyce, who was at the time Senior Plant Engineer at the London-based construction firm George Wimpey and Co. Limited, briefly mentioned that he had seen modifications done in South American countries to crawler tractors, excavators, and dumper trucks in order to improve their efficiency (by, for example, installing particular air filters to avoid damages from dust), or in order to enable them to carry

[140] Metres above mean sea level (or mamsl) is a standard metric measurement in metres of vertical distance (height, elevation or altitude) of a location in reference to a historic mean sea level taken as a vertical datum. This paragraph is based on: Maj. Gen. J.S. Bawa et. al., 'Question 1 Planning of Projects – Earthworks, India', in *PIARC* (Prague, 1971), 17 (hereinafter: Bawa et. al., 'Planning of Project – Earthworks, India').
[141] The D6 weighed 7.5 tons, or 9 tons with dozing equipment, while the D8 weighed nearly 18 tons with all the equipment. Taylor, 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Nigeria', 27.
[142] Taylor, 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Nigeria', 5.
[143] See e.g. Bawa et. al., 'Planning of Project – Earthworks, India', 8.

larger loads than they were designed to transport.[144] However, experience had also taught him that attempting to manufacture spare parts locally caused considerable difficulties and generated a great deal of downtime.[145]

In fact, the most significant obstacle for mechanisation was not environmental. The lack of spare parts was a constant concern, and the need to import them could present an additional obstacle in countries with imports restrictions, or where a government department was the employing authority and had fiscal control over the purchase of spares and materials.[146] In 1964, Joyce recommended getting experienced, trained personnel from the contractor's own organisation to vet the lists of all the spares needed for each type of machine – lists which were preferably obtained initially from the distributors or manufacturers of the machines.[147] He also suggested standardising the plant as much as possible to facilitate supplying the workshops, continuing the work while one machine was being repaired, and the training of mechanics and operators.[148] If standardisation was not possible on a large scale, he advised to at least try a degree of it with smaller units such as engines, compressors and electrical equipment.[149] Planning the supply, location and organisation of the repair workshops was also an important issue for road engineers, as well as the coordination of the plant.[150] For instance, in the mid-1960s, K. Nambiar from the Concrete Association of India attributed the failure to employ concrete-building machinery not only to the inability of small-sized crusher units to cope with the demand for aggregates, and to the lack of central mixing plants able to provide the necessary output of concrete to keep works running continuously, but also to poor coordination.[151] Concrete construction was mostly done by hand in India (with the help of mixers and hand-operated vibrating screeds).[152] Indeed, Nambiar insisted on the fact that unless jobs were planned and phased keeping in view the type of equipment to be employed, there was little chance for the mechanisation of construction.[153]

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[144] William Joyce, 'Civil Engineering Plant on Overseas Contracts', in *Conference of Civil Engineering Problems Overseas, Institution of Civil Engineers* (London, 1964), 322.
[145] Joyce, 'Civil Engineering Plant', 322.
[146] Joyce, 'Civil Engineering Plant', 318; Bawa et. al., 'Planning of Project – Earthworks, India', 8; K.K. Nambiar, 'Section 1 Construction and Maintenance of Roads and Runways, Question III, Design and Construction of Concrete Roads, India, in *PIARC* (Rome, 1964), 10 (hereinafter: Nambiar, 'Design and Construction of Concrete Roads, India'); PIARC, 'Proceedings of the XIVth International Road Congress – Question VII, Committee on Low Cost Roads', in *PIARC* (Prague, 1971), 279.
[147] Joyce, 'Civil Engineering Plant', 318.
[148] Joyce, 'Civil Engineering Plant', 319.
[149] Joyce, 'Civil Engineering Plant', 319.
[150] Joyce, 'Civil Engineering Plant', 320.
[151] Nambiar, 'Design and Construction of Concrete Roads, India', 9-10.
[152] Nambiar, 'Design and Construction of Concrete Roads, India', 9-10.
[153] Nambiar, 'Design and Construction of Concrete Roads, India', 10.

Manual labour was sometimes preferred for certain tasks, as in some cases it was cheap.[154] For instance, in India in 1961, the mechanisation of earthmoving was not considered necessary given the low cost of manual labour and due to the fact that the borrow pits along the roads required only short haulage.[155] According to the International Development Association (belonging to the Word Bank Group), the prevalence of unemployment made the use of manual labour in India not only possible, but also desirable 'to the greatest possible extent'.[156] In addition, in some instances manual labour was preferred because it was better suited to the task, the abilities of the workers, and the conditions of the site. For example, in Indonesia in 1951, in areas of heavy forest, clearing the route did not involve machine-sawing of trees because the machines were not designed for the hard tropical wood, their maintenance was difficult in the middle of the forest, and supplying their fuel was equally problematic.[157] It was found that experienced woodcutters could obtain the same results, and for a much lower cost.[158]

Road maintenance also underwent a process of mechanisation during this period, and the need to respond to local conditions prompted the emergence of innovative practices and artefacts for maintenance just as it did for construction. An instance of this is the variety of methods created to deal with corrugations (i.e. small transverse ridges that appear on the surface of unpaved roads in dry conditions). Corrugations were problematic because they became hard and thus rendered driving slow, unpleasant, damaging for the vehicles, and potentially dangerous.[159] Corrugations were very common in dry tropical climates, but were also encountered in areas of temperate climate during the dry season.[160] During the 1950s and 1960s there was no consensus about the exact causes of corrugations, or about how to prevent

[154] Although forced labour was abolished in many colonies by the middle of the century, in some places this process took longer (such as the Belgian Congo and Portuguese African colonies), and even where it was formally abolished some of its dynamics persisted – especially in relation to public works. See Introduction note 77.
[155] IDA, 'Appraisal of a Road Project for India', 8.
[156] IDA, 'Appraisal of a Road Project for India', 8.
[157] J.J. Jonker et. al., 'Sections 1 and 2 Joint Meeting, Question VI, Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, With Special Reference to Available Resources And to The Traffic to be Carried, Indonesia', in *PIARC* (Lisbon, 1951), 19 (hereinafter: Jonker, 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Indonesia').
[158] However, after cutting and drying and burning of the copped wood, the clearing process was finished with the help of bulldozers. Jonker, 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Indonesia', 19.
[159] After heavy rains corrugations could also render circulation impossible. J. Chauchoy and R. Lantenois, 'Low Cost Roads, French West Africa', in *PIARC* (Istanbul, 1955), 15, 26; Taylor, 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries. Nigeria', 20; NA, DSIR 27/353, RN/3017/JST, J.S. Tanner, 'Corrugations on Earth and Gravel Roads: their Formation, Treatment and Prevention' (April 1957), Summary (hereinafter: Tanner, 'Corrugations on Earth and Gravel Roads').
[160] Tanner, 'Corrugations on Earth and Gravel Roads', 1.

their appearance. In the 1950s, road research in different countries pointed to the fact that corrugations were linked to traffic: the heavier the vehicles, and the higher the number of vehicles per day, the faster the corrugations would appear.[161] However, factors such as the cohesiveness of the surfaces and the pressure of the vehicles' tyres also seemed to play a role, but the relationship between these factors was not understood.[162] Unless the road was paved, constant maintenance of the surface was necessary.[163]

In British African colonies, one of the simplest methods used to prevent corrugations was the employment of a branch cut from a bush (Figure 2.4). Brushes were effective on lightly trafficked roads when only spreading of loose material was required. The simplest form of manufactured brush was drawn by one or a few people, while more elaborate ones were towed by tractors (Figures 2.5 and 2.6). Another solution was the towed drag unit. Various types of drags were invented, particularly in West Africa where locally designed implements had been made. In the north of the Gold Coast, for example, a rolled steel joist was used (or a combination of short lengths of railway rail), loaded with concrete blocks according to the type and the state of the surface (Figure 2.7).[164] Graders were also employed to remove corrugations, and when manipulated skilfully they could remove even the worst ones.[165] Graders could spread loose material evenly, maintain an accurate camber, leave a good riding surface, and allowed a few workers to maintain several miles of road. However, they were expensive to buy, required skilled maintenance, and when operated by unskilled workers they could cause serious damage to a road.[166] An alternative was the method known as 'scuffling'. This consisted of first cutting out the corrugations with spaces, picks and hoes, to afterwards spread the loosened material over the road by hand. This was a slow and laborious method that required a relatively large force of unskilled labour.[167]

Figure 2.4 Hand-drawn brush made from thorn bush, ca 1957

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[161] Research had been done on the subject in Sweden, India, French colonial Africa, Germany, Argentina, and the US. See references in Tanner, 'Corrugations on earth and gravel roads', 13.
[162] R. Lantenois, 'Section 1 and 2 Joint Meeting, Question VIb, Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, with special reference to available resources and to the traffic to be carried – Allocation of funds to the construction and maintenance of these roads, French West Africa', in *PIARC* (Lisbon, 1951), 4, 11.
[163] Taylor, 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Nigeria', 20.
[164] In French West Africa different types of drags were invented as well (Chapter 3).
[165] Tanner, 'Corrugations on Earth and Gravel Roads', 5.
[166] Tanner, 'Corrugations on Earth and Gravel Roads', 5.
[167] Tanner, 'Corrugations on Earth and Gravel Roads', 6.

[Picture removed from ethesis version on copyright grounds]

Note: Figures 2.4 to 2.7 were all taken from: Tanner, 'Corrugations on Earth and Gravel Roads', Plate 1 (B), Plate 2 (A), Plate 2 (B), Plate 4 (A) – respectively.

Figure 2.5 Tractor-drawn brush made from thorn bush, ca 1957

[Picture removed from ethesis version on copyright grounds]

Figure 2.6 Tractor-drawn brush, ca 1957

[Picture removed from ethesis version on copyright grounds]

Figure 2.7 Drag unit as used in the Northern Territories of the Gold Coast for removing corrugations, ca 1957

[Picture removed from ethesis version on copyright grounds]

Roads for lorries and animal-drawn vehicles

In the developing world, in the 1950s and 1960s, the need to accommodate heavy vehicles was usually prioritised over other considerations, such as speed.[168] In fact, according to the IBRD, the findings of the AASHO Road Test of 1960 suggested that *only* heavy vehicles needed to be taken into account for the design of pavement thickness, as the effect of lighter vehicles was negligible in comparison.[169]

This made a significant difference for road design. The case of the Humming Bird Highway in British Honduras of the mid-1950s is illustrative. Until 1950 there were no motorable roads in Honduras: there was one rail line, and the country relied mainly on water transport.[170] The Humming Bird Highway was built to serve timber logging and to connect the area of citrus exploitation to the capital, Belize, and, at the same time, to expand the exploitation of raw materials to new areas. Despite a low traffic density, the surface needed to be thick and be made of a strong material like bitumen because timber trailers were common, and they could carry up to 20 tons (excluding their own weight and that of the tractor pulling it).[171] In addition, the carriageway was also wider than usual for one single lane (11 feet and 3 inches, instead of just 10 feet), because the road needed to offer easy passage for the large timber vehicles.[172] However, the precise effect that heavy vehicles had on different types of pavements, and its relationship with local conditions, was not a fully understood phenomenon in this period. The Humming Bird Highway was suffering from considerable deformation only 18 months after being in use.[173] By the early and mid-1960s, the international engineering community had established that the frequency of some heavy loads had a much more pronounced destructive effect than a large number of low or medium loads.[174] Therefore, the total of heavy loads carried annually was a decisive factor.[175] However, it

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[168] For instance, French engineers in French West Africa noted in 1955 that road alignments were not required to allow for high average speeds but they did, however, need to guarantee the passage of heavy lorries. J. Chauchoy and R. Lantenois, 'Section 1 Construction and Maintenance, Question III, Low-Cost Roads, French West Africa, in *PIARC* (Istanbul, 1955), 27.

[169] The IBRD recommended that, for practical reasons, when planning the thickness of a pavement, the effect of light loads (such as automobiles, pick-ups and light trucks) be neglected, as it was almost nil in comparison to the effect of heavy vehicles. International Bank for Reconstruction and Development, 'A Review of Highway Design Practices in Developing Countries' (Washington D.C., 1975), in TRB, *Compendium 1*, 213.

[170] Rowbotham, 'The Design and Construction of the Humming Bird Highway', 45.

[171] Rowbotham, 'The Design and Construction of the Humming Bird Highway', 76.

[172] Rowbotham, 'The Design and Construction of the Humming Bird Highway', 76.

[173] Factors included drainage problems. NA, DSIR 27-331, RN/2553/PHPW, PHP Williams, 'Roads and Road Problems in the Caribbean Area' (July 1955), 7-10 and Plate 39 (hereinafter: Williams, 'Roads and Road Problems in the Caribbean Area').

[174] Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France', 2.

[175] Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France', 2.

seems knowledge about this phenomenon was scarce, as even by the mid-1960s few engineers used load repetition to determine road design.[176] An important obstacle was the lack of data about traffic. Surveys providing information such as the variations of the most frequently encountered axle-loads, details on whether vehicles were empty, half-loaded or fully loaded, and the percentage of overloaded vehicles and their axle-load weight, were rare in these countries/colonies during the period.[177]

The circulation of animal-drawn vehicles in some parts of the Americas and Asia represented an additional problem. As mentioned in Chapter 1, the number of these vehicles was increasing in some countries and colonies in the post-1945 period. Different measures were adopted to accommodate such traffic. In Indonesia in the early 1950s, for example, to determine the necessary width of the road pavement, the engineers elaborated the following graph and concluded that 'a number of slow-moving vehicles (had) more influence on the pavement width than the same number of fast-moving vehicles'.[178]

Figure 2.8 Required pavement width with various traffic intensities of drawn carriages and motor vehicles, Indonesia, 1951

[176] Further research is needed to determine the impact of the concept of load repetitions in road pavement design over time (in general, and in the developing world in particular). In 1964, the British report at the PIARC meeting noted that more research was needed about the effects of different wheel-loadings and repetitions of load on the performance of gravel and bituminous-surfaced roads. It seems it is an issue that received increasing attention during the 1960s, even in the developing world. For instance in 1967, the Low Cost Roads Committee reported that some research was being done on the topic and that it had been found that in countries with a rainy season the problem of the effects of load repetitions was more acute because surfaces and foundations became weaker during prolonged rains, which could lead to temporary (and controversial) transit restrictions of the maximum axle-load weight allowed. Odier et. al., 'Particular Problems of Lightly Trafficked Roads, France', 2; R. Millard, 'Section 1 Construction and Maintenance of Roads and Runways, Question VI, Particular Problems of Lightly Trafficked Roads, Great Britain', in *PIARC* (Rome, 1964), 26-27; PIARC, 'Comité des Routes Économiques, Rapport, 1967', 63.

[177] In the late 1960s, the RRL had started experimenting with ways of making surveys providing data about the normal wheel-loads expected in Jamaica, Malaysia, Rhodesia and Malawi. The report suggests the RRL was also conducting these surveys in other countries, but no information was provided about them. R. Millard, 'Question VII Lightly Trafficked Roads, Great Britain', in *PIARC* (Prague, 1971), 15.

[178] Jonker, 'Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Indonesia', 7.

[Picture removed from ethesis version on copyright grounds]

Source: J.J. Jonker et. al., ‘Sections 1 and 2 Joint Meeting, Question VI, Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, With Special Reference to Available Resources And to The Traffic to be Carried, Indonesia’, in *PIARC* (Lisbon, 1951), 7.

Wide roads made the mixed traffic flow, but of course increased costs.[179] Indeed, the engineers noted that building two parallel roads, one for fast and another for slow traffic, could be envisaged in order to reduce the maintenance cost that a traffic of more than 100 iron-tyred carts could generate on bitumen roads.[180] An example of the application of this solution is the road built in 1950 between Jakarta and Kebajoran (a small satellite town that was supposed to draw off population from the capital). This road, meant to be a ‘great modern traffic-way’ included the construction of separate lanes for bullock carts, bicycles and pedestrians.[181] However, since Indonesia did not send reports to any other PIARC congress during the period, more research is needed to determine the extent to which traffic segregation was realised. It seems likely that parallel roads for slow-moving traffic were only provided along some main roads, given the increase in the initial cost of construction that segregation would require.

[179] Jonker, ‘Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Indonesia’, 6.
[180] Jonker, ‘Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, Indonesia’, 7.
[181] However, in rural areas it was usually impossible to ensure that the animal-drawn vehicles were using the lanes or paths provided for them – as was the case in Argentina in the 1930s. Anon., ‘An Indonesian Traffic-way, modern link between capital and satellite town’, in *Road International,* 1 (Autumn, 1950), 34-35; Pascal Palazzo, and Charles L. Coqueugniot, ‘The Segregation of the Various Classes of Traffic on the Highway, Argentina’, in *PIARC* (The Hague, 1938), 17-18.

The rising bullock-cart traffic in India (see Chapter 1) meant that the use of surface dressings was 'markedly different from that in most other countries' because of the need of finding a method that would produce roads capable of withstanding bullock carts.[182] Whereas usual surface dressings did not require the aggregate to be completely covered by the binder, in India engineers made sure this practice was followed, as they found it was the only way of making these surfaces resistant to the iron wheels of the bullock carts.[183] Another example of the influence of bullock carts in Indian road-building methods is concrete construction. At the 1964 PIARC congress, the Indian report on the construction of concrete roads started by stating that this technique had developed in India over the previous 40 years following a somewhat unique path.[184] This resulted partly from the fact that concrete roads arose from laying a cement concrete layer on top of existing water-bound macadam roads whenever the intensity and volume of traffic required an upgrade of the surface.[185] However, the road sections that had been chosen for a concrete surface were 'invariably those which carried high volumes of traffic or which had a preponderance of steel-tyred bullock carts'.[186] In fact, since the 1930s, despite its high initial cost, concrete had been used in India because it was found to be the only surface that could withstand heavy bullock-cart traffic, and not just motor traffic, as most paved surfaces could.[187] The high initial cost of the concrete was justified because the surface would considerably diminish maintenance expenditure in the long term.[188] By 1940, most Indian engineers deemed acceptable a 4" thick plain concrete pavement of premix construction over a macadam road.[189] Since this particular surface met the requirements of the bullock carts, a considerable length of rural roads was built according to that standard.[190] In the United Provinces, which was considered the province with the largest concrete mileage in the late 1930s (along with the princely state of Hyderabad), the majority of roads were made of kankar bound with tar or bitumen while only a small proportion of metalled roads was made of concrete.[191] However, the length of concrete roads

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[182] Nambiar, 'Design and Construction of Concrete Roads, India', 2.
[183] Millard, 'Road Building in the Tropics', 354.
[184] Nambiar, 'Design and Construction of Concrete Roads, India', 2.
[185] Nambiar, 'Design and Construction of Concrete Roads, India', 2.
[186] Nambiar, 'Design and Construction of Concrete Roads, India', 4.
[187] British Library (BL), India Office Records (IOR), IOR/V/27/710/3 Posts and Air Department, Post-War Road Development in India, *Proceedings of the Conference of Chief Engineers of Provinces and States, Nagpur* 15-18 December 1943 (Delhi, 1944), 7.
[188] Kynnerseley, T.R.S., 'Concrete Roads and the Bullock Cart', in *Journal of the Institution of Engineers (India)*, 9 (Sept. 1939), 141.
[189] Nambiar, 'Design and Construction of Concrete Roads, India', 4.
[190] Nambiar, 'Design and Construction of Concrete Roads, India', 4.
[191] The term metalled referred to roads built using a binding agent (such as water, tar or bitumen), as opposed to 'unmetalled' roads, i.e. earth roads which might or might not be drained, or bridged. D.P. Nayar, 'Construction of a concrete track in miles 306-310 of the Great Trunk Road (near Lahore), in *Minutes of the Proceedings of the Punjab Engineering Congress*, 27 (1939), 114; Government of India,

in the UP was multiplied by ten from 1929-30 to 1939-40, and the proportion of concrete roads compared to the total of metalled roads increased from under 1 per cent in 1929-30, to about 4 per cent in 1939-40, and to over 8 per cent in 1945-46.[192] In the mid-1960s, many of the concrete roads built in the 1940s were still in good condition and were found to have a compressive strength of concrete over 8,000 lb./sq. in.[193] Moreover, until the early 1960s, the way in which pre-moulded fillers were jointed prioritised the protection of the concrete from the tyres of the carts over the comfort demands of motor vehicle drivers:

> It was customary till about five years ago for the premoulded fillers to be kept slightly proud of the concrete surface and then caulked into the rounded joint groove, thereby making a high-riding joint. This was due to the fear that steel-tyred wheels of the bullock cart would otherwise strike the edges of the concrete slabs and cause spalling.[194]

Although this practice seemed to have yielded good results, as no special problems of the fillers were found even in the oldest pavements, it was modified in the mid-1960s due to the increased use of motor vehicles on heavily trafficked roads and the drivers' demand for a smooth riding surface.[195] Nonetheless, the effect of the carts' tyres continued to influence the construction of concrete surfaces until at least the early 1970s. For example, at the 1971 PIARC Congress, Indian engineers presented the construction of a 366 metres-long concrete street in Old Delhi that served heavy mixed traffic.[196] The top layer of the surface was made particularly strong so that the surface could bear the 'abrasive nature' of the high proportion of iron-tyred carts.[197] Although more research is needed to determine the proportion of concrete construction in relation to other paving methods, it is likely that concrete remained a small fraction of total paving due to its high initial cost (as it was until at least 1946).[198]

Report of the Indian Road Development Committee, 1927-28 (Calcutta, 1928), 9 https://archive.org/details/reportoftheindia032320mbp (24/09/2019); Sukla Bhaduri, *Transport and Regional Development, a Case Study of Road Transport of West Bengal* (New Delhi, 1992), 34.

[192] BL, IOR, IOR/V/24/3299-IOR/V/24/3309, United Provinces, Public Works Department, *Administration and Progress Report of the Chief Engineer, United Provinces Public Works Department, Buildings and Roads Branch*, 1929-30 to 1945-46 (hereinafter: UP, PWD, *Report Buildings and Roads Branch*).

[193] Some of the roads had, however, failed under axle loads of 12,000 lb. and over. Nambiar, 'Design and Construction of Concrete Roads, India', 4.

[194] Nambiar, 'Design and Construction of Concrete Roads, India', 11.

[195] Nambiar, 'Design and Construction of Concrete Roads, India', 11.

[196] Concrete was more common in urban areas. J. Datt, 'Question III Concrete Pavements, India', in *PIARC* (Prague, 1971), 14.

[197] J. Datt, 'Question III Concrete Pavements, India', in *PIARC* (Prague, 1971), 14.

[198] Concrete roads represented 8 per cent of total paved roads in 1945-46. UP, PWD, *Report Buildings and Roads Branch*, 1929-30 to 1945-46.

Conclusion

A modernisation process based on the American model of road engineering took place and made possible the growth of heavy traffic over low-cost and often unpaved roads that characterised the developing world during the period. The particular environmental, traffic, administrative and institutional characteristics in these areas necessitated the emergence of new knowledge, and was therefore perceived by road engineers (particularly by engineers from developed countries) and by the World Bank staff as distinctive endeavours. These peculiar challenges also prompted the emergence of solutions that although often based on equipment and techniques from developed countries, took new and unique shapes. Methods and standards were modified and hybridised; mechanisation spread as long as machines and work regimes were adapted to local conditions (and as long as the task demanded it and the environmental and economic contexts allowed it), and sometimes completely new artefacts emerged to confront particular problems, like corrugations. Finally, the design of road structures also differed to that of developed countries, especially where roads needed to accommodate high proportions of heavy lorries and, sometimes, animal-drawn vehicles. Scarcity of funds and organisational and managerial limitations often restricted the extent to which the solutions considered ideal were applied. In fact, it seems that while tools and techniques were imitated and modified, management and administration practices were not, or to a lesser extent, considerably limiting the efficacy of the modernisation of road construction tools and techniques.

Chapter 3 Building and maintaining roads in French West Africa and the Algerian Sahara, 1950-1962

After the Second World War, roads in French African colonies were mainly intended to carry goods over long distances at the lowest possible cost. The priority of the white, French engineers (mostly graduates from the École des Ponts et Chaussées) was to accommodate increasingly heavier lorries while keeping construction and maintenance costs to a minimum. This task was particularly challenging because they had to confront extremely varied and constraining environmental conditions that differed considerably from the ones they were familiar with in the metropole.

This chapter explores how they were able to do so through the examples of French West Africa (FWA) and the Algerian Sahara, from 1950 until independence. Although both territories were very important in economic, political and military terms, the resources available in the Sahara were much greater. In fact, while FWA's roads transported mostly exports of coffee, cacao, timber and bananas, road construction in the Sahara was motivated by hydrocarbon exploration and exploitation. These differences generated two different types of efforts in this period. In the Sahara, massive investment from both the colonial administration and private firms resulted in the building of new paved roads with modern and novel methods adapted to the extreme conditions and demands. In FWA, this period was mostly characterised by the establishment of a highly successful mechanised maintenance regime that made existing low-cost roads able to carry rising volumes of goods.

These two cases illustrate the post-war modernisation of road engineering presented in Chapter 2, and in particular the important influence of the US model. In addition, this chapter, as well as the two following ones, show that maintenance played a key part in the push towards the technical, technological and scientific development related to road and road transport development. The importance of maintenance was evident in that it was present in all stages of road development: from materials research, to creation and use of construction and maintenance plant, passing through drainage and profile design. Furthermore, this chapter goes beyond the recent initiatives to analyse the role of maintenance (see Introduction), by presenting it not as the neglected routine upkeep of roads, but as a central activity in road development that occupied everyone from labourers to elite engineers and that involved the use of innovative methods and instruments.

Moreover, through the case of the Sahara this chapter reflects on the meaning of environmental constraints (see also Chapter 5). I argue that the biggest challenge posed by the natural environment was the lack of knowledge about the way in which both local and imported materials would behave if they were employed for road construction in this context. There was no precedent for the use of certain familiar materials in these extreme conditions (like bitumen), and the properties of the local materials (mostly sands) were unknown. Given that the kind of new knowledge the engineers needed about local materials could only be produced in materials laboratories, these facilities acquired major importance in road construction projects. Yet, the roads built in the Sahara during this period remained experimental to a certain extent, as it was considered that only time would be able to confirm laboratory findings. Unlike the other case studies in this thesis, the case of the Algerian Sahara features the construction of paved roads and the swift upgrade of tracks into paved roads. The hydrocarbon roads do not seem to have been considered low-cost.

This chapter is divided into two main parts. The first section focuses on the Algerian Sahara and highlights the role of private firms and materials laboratories in the development of paved roads. The second section studies the case of FWA and gives special emphasis to the territory of Ivory Coast given its commercial importance within the federation. The chapter is based on two main sources. First, the colonial Public Works fund at the Archives Nationales d'Outre-Mer (ANOM, Aix-En-Provence, France). This archive contains published and unpublished documents related to transport projects that took place in the French colonial Empire during the twentieth century. The documents include annual technical and administrative reports and proposals and assessments of the transport development plans. The second important source is the monthly journal *Revue Générale des Routes et des Aérodromes*, a private publication that features contributions from engineers working either for the colonial administration or for private firms, being all these engineers for the most part graduates of the École Nationale des Ponts et Chaussées. The *Revue* can be found in Paris at the Bibliothèque Nationale de France (François-Miterrand site).

Urgent roads for the 'unknown': the roads of the Algerian Sahara, 1956-1962

In 1947, France launched a vast exploration programme to find hydrocarbons in the Algerian Sahara. In 1956, after four years of exploratory drillings, large oil reserves were found in Ejdeleh (100 million tons) and in Hassi-Messaoud (600 million tons), while one of the world's largest gas fields was discovered at Hassi R' Mel.[1] These discoveries, and the efforts that led to them, transformed road transport in the Algerian Sahara. This section presents the steps taken by the public administration (i.e. the newly created Organisation Commune des Régions Sahariennes, OCRS) and mostly private construction and petroleum firms in order to build the roads that served oil and gas fields and make them accessible. Long distances, extreme climate and the rising circulation of the new large vehicles especially designed for the Sahara made this endeavour extremely challenging and expensive. However, the greatest obstacle for the road engineers was the limited knowledge they had about the properties of the local materials, and especially about how these would behave if used for road construction in those particular conditions. Similarly, the way familiar materials would react in this context was unknown. The adoption of materials laboratory testing and other modern American techniques was a key part of the process of road construction in the Sahara. New ways of managing and organising labour and road works also had to be created in response to the conditions. However, it is noted that although many innovations were required, existing 'old' techniques were also employed in this endeavour. The term 'low-cost' was not employed in this context, although engineers were always looking for ways to keep costs to a minimum.[2]

This section is divided into four parts. The first part gives a broad picture of the transport system in the Algerian Sahara before 1950 and presents the main challenges to road construction in the region. The second part focuses on the upgrade of the Ghardaïa-El Goléa route from a track into a paved road, emphasising the modern equipment and techniques used, as well as the role of large private companies. The third part presents the example of the construction of the Gassi-Touil road, a paved road crossing the Great Eastern Erg, highlighting the major role that laboratory testing played. The final part briefly introduces certain particularities of the construction of roads within oil fields.

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[1] Marta Musso, 'Oil Will Set Us Free: The Hydrocarbon Industry and the Algerian Decolonization Process', in Andrew Smith and Chris Jeppesen (eds.), *Britain, France and the Decolonization of Africa: Future Imperfect* (London, 2017), 67-68.

[2] I only found one reference to the construction of 'economical' roads built quickly and with the expectation that future improvements would be needed. This comment was made by André Ponton in a recent volume gathering testimonies from engineers of the École des Ponts working in African colonies; Ponton arrived to Algeria in 1950 to work for the administration, who was put in charge of the technical services of the OCRS in 1960 and continued to direct the organism that replaced the OCRS after independence until 1964. He characterised as economical the roads the engineers built in the 1950s and 1960s around Touggourt, El Oued, Ouargla, Ghardaïa, amongst others. In general, however, although engineers in the Sahara were always trying to minimise costs, they commented on the availability of abundant funds. In addition, due to environmental and traffic conditions roads were paved and made highly resistant. Jacques Bourdillon (ed.), *Les Ingénieurs des Ponts au Service de l'Afrique, Témoignages 1945-1975* (Paris, 2010), 241-46.

Setting the scene: desert, hydrocarbons, lorries

In the first decades of the century there was little transport development in southern Algeria. Rail connections between the main coastal cities and the south followed three main axes: the western axe went from Oran to Colomb-Béchar, the central one from Algiers to Djelfa, and the eastern axe from Philippeville to Touggourt. These railways served military and political purposes as part of the French effort to control the Southern regions of their Northern African colonies.[3] South of these termini, caravans were the main methods used to supply the oases and provide administrative connections.[4] Caravans of dromedaries followed ancient routes towards Sudan, Niger or Chad, and south of the Eastern Erg transport was limited to the traditional itineraries of semi-nomad tribes on the border between Algeria and Tunisia.[5] A network of motorable roads and tracks also existed, following the same three axes as the railways and reaching further south across the desert. Even though motor traffic was light, by the middle of the century the northern stretches of the roads linking the coast to the Sahara were covered by a light bituminous treatment. These roads connected Oran to Bouktoub (in the route towards Colomb-Béchar, stretching for 280 km), Algiers to Laghouat and the oasis of Ghardaïa (635 km-long road, known as the RN1), and Philippeville to Biskra (320 km-long, in the route towards Touggourt).[6]

Figure 3.1 Map of Saharan roads and tracks, 1957

[3] Saigot, J., 'Préambule: Les Travaux d'Infrastructure au Sahara de 1945 à 1957', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 65.
[4] Saigot, 'Préambule', 65.
[5] Saigot, 'Préambule', 65; Réné Durand, Marcel Tessier and Charles Jaillard, 'La Circulation dans les Ergs du Sahara', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 156.
[6] Saigot, 'Préambule', 67.

[Picture removed from ethesis version on copyright grounds]

Source: Taken from J. Declerck, 'Roads for the Sahara', in *Road International*, 27 (1957), 31.

The quest for and discovery of hydrocarbons revolutionised transport in the Algerian Sahara.[7] This revolution did not include railways. Although there were plans to build rails across the desert by the late 1950s, these were never built, and all transport south of the railway termini was done by road or track throughout the period.[8] Roads were indeed the preferred method for petroleum exploration because it was a highly uncertain activity.[9] There were two types

[7] During the Second World War, the railway that connected Oran to Colomb-Béchar was extended south as part of an initiative to build a Trans-Saharan Railway, an ambitious project that was never built. The railway only made it to Abadla, less than 100 km away from Colomb-Béchar. Some road paving took place during the war as well, in the area linking Touggourt to Ouargla and some stretches in the route Ouargla-Fort-Lallemand, but these were only 250 km in total. Saigot, 'Préambule', 65-67.
[8] See map, Annexe D.
[9] G. Kyvellos, 'Infrastructure Saharienne de la Compagnie Française des Pétroles (Algérie)', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 221.

of roads and tracks linked to hydrocarbons: the long-distance access routes (that connected coastal cities to the exploration/exploitation fields), and the roads within exploitation camps.[10] While the latter were built and managed by hydrocarbon firms, the former were provided by both this type of firm and large groups of French construction firms hired by the public administration.

The construction and upgrade of roads to serve the new hydrocarbon needs confronted the French engineers with obstacles that had not been surmounted before in road building. Climate conditions were certainly one of the biggest problems to overcome, but the real issue was that there were no previous studies about the behaviour of materials under such extreme temperatures (that could oscillate in some places from 0 to 80º C under the sun), and the effects of humidity variations on the roads were difficult to predict in the long term.[11] There was a lot of uncertainty around road construction and maintenance in the Sahara, but two threats were quickly identified as absolutely certain: sand and water. Sand storms could bury the roads, and while rain was very scarce, it could be torrential. Flooding frequently destroyed roads, and road foundations could remain humid at 5 per cent for many weeks after heavy rain, causing great instability.[12]

In addition, access to water for road works was difficult, traditional road-building materials were rare, and there were no detailed maps of the region. In fact, in the 1950s the maps offered by the administration were of poor quality and although the nomad populations knew the territory well, their knowledge was not directly translatable into conventional figures and information that would allow the engineers to exploit it.[13] One of the possible reasons for the difficulty of employing their knowledge in road construction is the fact camel routes were not designed to accommodate motor vehicles, and the latter often found it impossible to circulate on these routes.[14] Another important reason was that the properties of local materials played

[10] For a map of Saharan roads and tracks in 1957 see Figure 3.1.
[11] Barbet, G. and Masson, P., 'Le Rôle de la Route au Sahara. Ses Conditions d'Établissement et d'Exécution', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 86.
[12] Saigot, J., 'Section 1 Construction and Maintenance, Question 3 Low-Cost Roads, Algeria', in *Permanent International Association of Road Congresses* (Istanbul, 1955), 5 (hereinafter: Saigot, 'Low-Cost Roads, Algeria'); J. Fonkenell and G. Guérin, 'La Route Gassi-Touil, Construction d'une Route en Matériaux Exclusivement Sableux', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 190.
[13] Barbet and Masson, 'Le Rôle de la Route au Sahara', 84.
[14] To overcome the lack of maps, aerial photography was employed. Used in the US since the 1920s, aerial photography had become popular in British African colonies to compensate for the lack of maps or, more accurately, the lack of detailed maps to work with. In the Sahara this was a particularly useful technique because the lack of dense vegetation made the determination of the topography and the materials of the terrain relatively easy. Moreover, aerial photography was seen as a suitable alternative to the traditional manual terrain reconnaissance because it required a lot less time, effort, and money. Barbet and Masson, 'Le Rôle de la Route au Sahara', 84.

a major role in the process of deciding which route to take – but these characteristics could only be determined with laboratory tests.

Moreover, population density was low, services for drivers were scarce, and distances were very long.[15] This made the transport of materials expensive and the management of labour and plant complicated. For example, the transport of bitumen was so expensive that only traffic of over 70,000 or 100,000 tons per year justified its use.[16] In fact, bitumen was imported from the refineries of the Étang de Berre (South-East France) and stored in different coastal cities; the largest stocks were located in Oran (storage capacity of 7,700 tons) and Algiers (with the capacity to store 7,500 tons).[17] From there, most of the bitumen would be transported by railway on tank cars until the terminus (Touggourt in particular), from where it would be transferred to lorries which, in turn, would deliver the binder to the work sites.[18] Sometimes the distances the lorries had to cover were of more than 1,000 km return.[19]

Finally, the Saharan vehicles that had started being developed since the beginning of the century also represented novel challenges. These vehicles were not only becoming increasingly adapted to the heat, dust, and long distances, they were also growing in size and loading capacity to serve the hydrocarbon sector.[20] By the late 1950s, loaded lorries could weigh about 40 to 70 tons, and axle loads could reach 15 tons (which exceeded the maximum allowed in France, i.e. 13 tons).[21] Despite low traffic densities (sometimes no more than 50 vehicles per day), these heavy vehicles were a threat to the road structures and surfaces, especially because the effects of their circulation were only being researched at the time.[22]

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[15] For instance, the distance between Touggourt and the oil field of Edjeleh is over 900 km-long.

[16] In 1959, construction with bitumen was estimated at 10 million francs per km in the Northern Sahara and at 15 million francs in the Central Sahara. Saigot, 'Préambule', 70.

[17] Chambre Syndicale des Importateurs et Distributeurs de Bitumen de Pétrole en Algérie (CSIDBPA), 'Approvisionnement et Distribution des Liants Bitumineux sur les Chantiers Sahariens, Départements des Oasis et de la Saoura', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 219.

[18] CSIDBPA, 'Approvisionnement et Distribution', 218.

[19] There were companies specialised in the transport of materials. They crafted diverse solutions for these long journeys. Amongst these was the use of articulated lorries towed by a tractor of 300 hp. with adapted tanks designed to keep the bitumen hot – the total weighing about 60 tons when loaded. CSIDBPA, 'Approvisionnement et Distribution', 218.

[20] See R. Le Grain-Eiffel, 'La Construction Automobile Française de Véhicules Sahariens', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 141-154.

[21] P. Fumet, 'Étude de l'Action des Véhicules Gros Porteurs Sahariens sur l'Infrastructure Routière', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 129; P. Fumet, 'Chaussées en Sables Gypseux et en Sables Stabilisés Chimiquement', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 169-178.

[22] Le Grain-Eiffel, 'La Construction Automobile Française'. In 1959, on the 110 km-long stretch open to traffic on the Gassi-Touil road (which was still under construction), traffic density was on average 50 vehicles per day, but lorries could weigh up to 70 tons; the average weight bore by the road was 150,000 tons per year. Fonkenell and Guérin, 'La Route Gassi-Touil', 189.

Upgrading tracks into roads: the Ghardaïa-El Goléa road and the role of construction firms

From 1951 to 1954, hydrocarbon exploration generated a significant traffic increase on the 320 km-long track connecting Ghardaïa to El Goléa. In only three years traffic volume was multiplied by seven, reaching 51,000 tons per year.[23] Since this traffic was only expected to increase, the administration decided to upgrade this route into a road that could withstand vehicles of 13 tons per axle circulating at 100 km/h – as this was the only way to keep the road open and keep maintenance costs manageable.[24] Reconnaissance studies started in 1956, and construction in October 1957.

The construction of this road is an example of the rapid modernisation that road construction experienced in the Sahara in the mid- to late-1950s. The scale of works and the conditions of the site meant that a group of construction companies (and not just one) was in charge of the project. In this case, the bid was won by the Groupement des Entreprises pour l'Aménagement des Routes du Sahara (GEDARS), which consisted of the large firms: Société Colas d'Algérie, Société Générale d'Entreprises (SGE, today's Vinci), Razel Frères, and Truchetet et Tansini.[25] GEDARS spent over 3,100 million francs in the construction of this road.[26]

In addition, the selection of materials was done with the help of modern laboratory tests – a reconnaissance process that took about six months.[27] The structure and type of surface were determined according to these findings and following the construction of experimental stretches. From early- to mid-1957, GEDARS built a few stretches of the road with different surfaces to see how they would react to traffic. After two months, it became clear that a thick bitumen surface was needed, especially if the effects of the high temperatures on the bitumen were to be delayed, as the American experience had previously shown. The consideration of

[23] Saigot, 'Low-Cost Roads, Algeria', 2.
[24] C. Regis and J.P. Fourès, 'La Construction de la Route de Ghardaïa à El Goléa', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 209-13.
[25] Regis and Fourès, 'La Construction de la Route de Ghardaïa à El Goléa', 210.
[26] By June 1959, with still 50 km left to build, the cost of the works had been 3,100 million francs. However, these companies did not work exclusively within GEDARS. In fact, construction companies formed different groups for every project (or for a certain number of projects). For example, Société Colas d'Algérie, SGE, Razel Frères and Truchetet et Tansini joined forces with Viasphalte and the Société Algérienne de Travaux Publics de l'Afrique du Nord (SATPAN) to build about 450 km of roads from 1954 to 1959, costing over 4,000 million francs (their projects included the roads from Biskra to Touggourt and Ouargla to Hassi-Messaoud). Robert Warren and Jacques Fourès, 'Organisation, Rôle, Effort de l'Entreprise Routière au Sahara', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 94.
[27] For more details about the use of laboratories in the Sahara see next section. This paragraph is based on: Regis and Fourès, 'La Construction de la Route de Ghardaïa à El Goléa', 210-13.

the response of the road to future traffic and the local natural environment was indeed essential to facilitate future maintenance and delay reconstruction as much as possible.

The American influence was not only present in the use of materials laboratory tests and the choice of surface, but also in the mechanisation of works and the plant employed. For example, although some of the equipment used to build the surfaces was indeed French (a Richier cylinder, a Berliet lorry, and an Albaret roller), the majority seems to have been American, including two 'Heavy Duty' Barber-Greene bituminous mixing plants, one bulldozer D7 (Caterpillar), one bulldozer TD14 (International Harvester), one motor-grader (Caterpillar), and one Barber-Greene finisher.[28]

Conditions in the Sahara also required the creation of new management practices. The maintenance of the machinery had to be pushed to an extreme, as expensive and sophisticated machines would be useless unless they were adequately maintained, lubricated and promptly repaired. For instance, the availability of spare parts had to be planned well in advance due to the long distances and also because, as the engineers Robert Warren and Jacques Fourès stated in 1959, 'in the Sahara… you only find what you take with you'.[29] Moreover, despite the high mechanisation of the work, large numbers of workers were required, partly because the isolation of the work sites made necessary a great variety of workers that went from mechanics, to cooks and nurses.[30] Although mobile accommodation for workers on road construction sites was very common in large projects in this period, the peculiarity of the Saharan caravans was that they had to provide air conditioning for temperatures up to 55ºC.[31] In addition, the construction companies were aware of the strain on the workers' mental health that working for prolonged hours under the sun hundreds of kilometres away from the nearest town could cause. Different solutions were implemented such as offering periods of leave every 5 to 6 weeks, bringing by lorry or by plane diverse commodities for the workers to buy, and even offering entertainment, such as open-air cinemas in the middle of the desert.[32] The idea was to give the workers the impression that 'they never left'.[33]

[28] The brand of smaller equipment and tools was not specified, but it is likely that it was produced in France. Regis and Fourès, 'La Construction de la Route de Ghardaïa à El Goléa', 213.
[29] Warren and Fourès, 'Organisation, Rôle, Effort', 92.
[30] In 1959, for a road programme of 1,400 km taking place over four years (and costing about 17 billion francs), the number of workers was about 1,500. Warren and Fourès, 'Organisation, Rôle, Effort', 95.
[31] This accommodation also differed from the one provided for oil fields because it needed to be mobile. Warren and Fourès, 'Organisation, Rôle, Effort', 95 ; Bourdillon, *Les Ingénieurs des Ponts au Service de l'Afrique,* 259.
[32] Warren and Fourès, 'Organisation, Rôle, Effort', 95.
[33] Warren and Fourès, 'Organisation, Rôle, Effort', 95.

Building a new road across the Eastern Erg: the Gassi-Touil road and the role of materials laboratories

The Gassi-Touil road was built from 1957 to 1960; it connects to this day the region around Hassi-Messaoud (and therefore, northern Algeria) with Fort-Flatters (and from there the oil field of Edjeleh).[34] Although traffic was already in circulation along this corridor before 1957, only about a third of the route corresponded to a built road at the time.[35] The hydrocarbon findings around the Edjeleh area justified the construction of this paved road, as the maintenance of any other surface would prove too expensive with the rising traffic.

Conditions in Gassi-Touil were considered to be extreme, even by the standards of other Saharan road works.[36] Crossing the Great Eastern Erg from north to south, the route extended for about 300 km along a corridor surrounded by dunes. The temperatures reached 50°C in the shade from May to September, period during which water consumption could reach 500 m^3 per day, due to evaporation. The isolation of the site presented challenges for both the workforce and the plant. As previously mentioned, long stays in these conditions were considered dangerous for the mental health of the workers. The closest oasis, Ouargla, was situated 400 km away from the starting work site. Communications were also an important issue: radio connection with Algiers was considered indispensable to order and receive plant and materials as promptly as possible.

However, the major obstacle was the lack of materials that were traditionally used for road construction. In order to determine whether it was possible to use any of the materials alongside the route, laboratory tests were employed. From April to December 1957, materials were analysed and classified at the mobile laboratories at the work site, and smaller representative samples were sent to the Laboratoire Central des Ponts et Chaussées (Algeria Division) for more detailed studies.[37] The tests performed included granulometry, plasticity, CBR, and other standard tests (see Chapter 2), and produced essential new knowledge to build the road.

The role of the laboratory went beyond the testing of local materials. It was considered necessary to stabilise the superior layer of the base given the expected traffic of lorries

[34] I have not been able to find an exact date of completion, but in 1959 the completion date was December 1960. Warren and Fourès, 'Organisation, Rôle, Effort', 94.
[35] Fonkenell and Guérin, 'La Route Gassi-Touil', 179.
[36] This and the next paragraph are based on : Fonkenell and Guérin, 'La Route Gassi-Touil', 179-80.
[37] Fonkenell and Guérin, 'La Route Gassi-Touil', 180.

weighing over 60 tons.[38] However, known stabilisation methods were considered too expensive (in particular sand-cement) and it was the collaboration with the laboratory in Algiers which allowed the construction to move forward, with the discovery of the possibility of using a 'miracle' material: lignosulfonates.[39] This material is a by-product of the production of paper, at the time produced in Landes, and it was useful as a binder for road construction only if it was not exposed to humidity, which was the case in this area.[40] The construction of this road absorbed almost all French production for three years.[41] It was transported by train until Port Vendres, by ship to Philippeville, by train until Touggourt, and from there by lorry until the road site.[42] Furthermore, materials laboratories were also essential during construction to monitor the characteristics of the materials being used. In addition to the laboratory situated at the semi-permanent camp (moved every 100 km), staff from the Algiers laboratory were sent to perform measurements on site during construction.[43]

It is worth noting that, despite the increasing use of laboratories, by 1959 experience was still considered necessary to determine the efficacy of construction and maintenance techniques. Indeed, although private companies (such as the Société des Transports Pétroliers par Pipeline, TRAPIL, and the Union Technique de l'Automobile, du motocycle et du Cycle, UTAC) and the Central Laboratory of the École des Ponts contributed enormously to the knowledge of local materials, it was still considered that the results from the experiments could only be confirmed by commercial use.[44]

In fact, not everything about transport in the Sahara was new in the 1950s. Most of the routes across the Sahara were either ancient itineraries or were at least used since the First World War. Routes across the ergs (or sand seas) were still being marked by guemiras (rock pyramids used by the méhariste militaries) or their updated version made of metal or plastic.[45] The gypsum sand, never before used for roads, was used before in artisanal construction, and

[38] Fonkenell and Guérin, 'La Route Gassi-Touil', 181.
[39] Bourdillon, *Les Ingénieurs des Ponts au Service de l'Afrique*, 263.
[40] Rain was considered negligible. Bourdillon, *Les Ingénieurs des Ponts au Service de l'Afrique,* 263.
[41] Bourdillon, *Les Ingénieurs des Ponts au Service de l'Afrique*, 263.
[42] After this road was finished, the experience acquired was only partially transferable to build the stretch that reached In Amenas (and thus Edjeleh). Bourdillon, *Les Ingénieurs des Ponts au Service de l'Afrique*, 263.
[43] Fonkenell and Guérin, 'La Route Gassi-Touil', 182-88.
[44] Charles Deutsch, 'Pipelines et Transports Automobiles Sahariens', in *Revue Générale des Routes et des Aérodromes*, Spécial Sahara, 29 (June 1959), 112.
[45] Durand et al., 'La Circulation dans les Ergs', 160.

water, needed in large quantities for the construction process and for the workers, was often obtained with the ancient method of the artesian well.[46]

Roads in oil fields

Although traffic on oil exploitation fields could be extremely heavy, road planning was relatively easy given that the circulation of vehicles was highly controlled, unlike the traffic on public roads. In the camp of Hassi-Messaoud, for example, the Compagnie Française des Pétroles - Algérie (CFP) calculated traffic on roads according to 'units of traffic'. One unit of traffic corresponded to 2,000 passages of heavy lorries (10 to 55 tons), and 4,000 passages of light vehicles, i.e. a total of 50,000 tons in the period of 5 to 6 months.[47] The characteristics of each road within the network were determined according to the number of units of traffic that particular road was expected to bear: although most roads were paved, some roads only received a soil stabilisation treatment.[48]

To illustrate the scale of the works, in one block of the camp (of about 40 sq. km), 620 km of roads were needed, and traffic was expected to oscillate between one and four units of traffic.[49] In a period of six months the total volume of traffic in the Hassi-Messaoud network was expected to be approximately 10 units, i.e. 500,000 tons (unevenly distributed). Although the cost of the works was not made explicit, one of the engineers of the CFP estimated in 1959 that they would cost a few billion francs. Apart from road networks, the CFP also provided exploration drills with aerodromes whose size depended on the importance of the camp. In Hassi-Messaoud, for example, an aerodrome equipped to receive heavy planes of 55 tons was built.

The construction of pipelines also required building tracks. Indeed, the first step in pipeline construction was to build a track of 15 to 20 m-wide.[50] These tracks were mainly used by transport vehicles and work machinery (which included tractors and other machines, such as welding equipment). The material transported included pipes, water, lubricants, and surfacing materials, amongst others, the transport of which necessitated a large fleet of about 100 mobile units (lorries or tractors), representing about 25,000 hp (i.e. more than work

[46] Fumet, 'Chaussées en Sable Gypseux', 169; Anon., 'Construction de La Route Ghardaïa-Ouargla', in *Revue Générale Des Routes et des Aérodromes*, 317 (1958), 91.
[47] Kyvellos, 'Infrastructure Saharienne', 221.
[48] Kyvellos, 'Infrastructure Saharienne', 222.
[49] There were roads that were expected to carry more than four units of traffic but these were a minority. This paragraphs is based on: Kyvellos, 'Infrastructure Saharienne', 221-23.
[50] These pipeline tracks differed from tracks built for motor vehicles in that they followed the sharp curves of the pipes. This paragraph is based on: Deutsch, 'Pipelines et Transports', 112.

machinery, which usually had a power of 15,000 hp), as well as about 150 units of towed equipment, such as trailers and tanks.

Maintaining low-cost roads in French West Africa, 1950-1959

After the Second World War, FWA, the largest of the federations in 'Afrique Noire', comprised the territories of Senegal, French Guinea, Ivory Coast, Dahomey, Mauritania, French Sudan, Upper Volta, Niger and French Togoland – in the late 1950s it was estimated that the Federation extended over an area of 4,634,000 sq. km, comprising a population of about 19 million.[51] This area corresponded to about double the one of the second largest federation, French Equatorial Africa, and to about seven times the area of France.

Roads occupied a central role in the development agenda of FWA in the post-war period. By 1957, lorries were carrying a larger freight volume than railways on mostly unpaved roads.[52] These were low-cost roads, and only the establishment of a large-scale and strict regime of constant routine and 'progressive' maintenance (also called stage construction, see Chapter 2) allowed for the circulation of the rapidly growing traffic. This new way of organising maintenance made use of new modern machinery and obtained very satisfactory results. By 1959, the engineers working in FWA, and especially in Ivory Coast, considered they had found a way of maintaining unpaved roads that could and should be widely applied. This method was mainly based on highly frequent interventions, the employment of trained engineers for the supervision of teams and, above all, on the modification of road design to make maintenance easier and cheaper.

In the early 1950s, FWA had a railway network of about 3,700 km, which consisted of unconnected lines, each serving a separate territory linking the inland productive areas with the maritime ports – the largest ones being Dakar, Conakry, Cotonou and Abidjan (opened respectively in 1866, 1909, 1892, and 1951).[53] The road network consisted of about 47,000

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[51] French Togoland had a particular status; in 1955 it became an autonomous republic within the French Union while retaining the status as a UN trust territory that it acquired after the Second World War. However, for public works planning, Togoland was effectively managed as part of French West Africa until its formal independence in 1960. M. Giraud and J. Millier, '1ère Section: Caractéristiques, Construction et Entretien des Routes et Pistes d'Aviation, 4ème Question: Routes à Faible Prix de Revient, Rapport Afrique Occidentale Française' in *Permanent International Association of Road Congresses* (PIARC) (Rio de Janeiro, 1959), 2 (hereinafter: Giraud and Millier, 'Routes à Faible Prix de Revient').

[52] It seems most of these roads were built before 1950. See note 54.

[53] IBRD, 'Technical Report on the French West African Railways' (Washington D.C., 24 May 1954), Table 1.

km of road and 34,000 km of tracks, i.e. about 0,01 km of road per sq. km (excluding tracks).[54] Roads and tracks followed a similar pattern to the railways (and therefore ran parallel to them), with the difference that roads also provided inter-colonial connections with northern Africa, as well as reached much extensive territory by feeding the railways and main road routes.[55]

Before the Second World War, roads and tracks were built by the army and France d'Outre-Mer (FOM) administrators with little resources, and it was only after 1946 that engineers from the École des Ponts were sent to sub-Saharan Africa to work on infrastructure projects.[56] By the early 1950s, most of the network was seasonal and unpaved, and road conditions were poor: drainage works were considered insufficient, tracks could not keep up with the traffic demands and were rutted by traffic and surface water, and tracks with light treatments were constantly deteriorating.[57] This situation was changed by the end of the decade, when dust seemed to be the only remaining problem.

This section is divided into two parts. The first one presents the objectives and challenges of FWA's road development from 1950 to 1959. The second examines the way in which mechanised maintenance regimes were established during the period in FWA, and in Ivory Coast in particular. The example of Ivory Coast is used prominently in this section, not only because of its successful maintenance regime, but also because of its important economic role within FWA. In fact, in 1955, the value of Ivory Coast's imports and exports corresponded to almost 40 per cent of the external commerce of FWA, and in particular, to more than 70 per cent of the total exports of FWA.[58]

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[54] These figures are from 1956 but length increase seems to have been negligible in the previous five years. See Annexe F and: R. Lantenois, 'Section 1, Road Construction and Maintenance, Question II, Progress Made Since the Congress at The Hague in 1938 in the Study of Road Subgrades, French West Africa', in *PIARC* (Lisbon, 1951), 2.
[55] See map in Annexe E.
[56] Bourdillon, *Les Ingénieurs des Ponts au Service de l'Afrique*, 378.
[57] R. Lantenois, 'Section 1 and 2 Joint Meeting, Question VIb, Construction and Maintenance of Roads in Thinly Populated or Under-Developed Countries, With Special Reference to Available Resources and to the Traffic to be Carried – Allocation of Funds to the Construction and Maintenance of these Roads, French West Africa', in *PIARC* (Lisbon, 1951), 2, 3 (hereinafter: Lantenois, 'Construction of Roads in Thinly Populated or Under-Developed Countries'); R. Lantenois, 'Section 1, Road Construction and Maintenance, Question II, Progress Made Since the Congress at The Hague in 1938 in the Study of Road Subgrades, French West Africa', in *PIARC* (Lisbon, 1951), 2.
[58] The value of Ivory Coast's imports was of 19 billion CFA francs and the value of its exports was of 25.6 billion CFA francs. The most important export products were: coffee and cacao, timber, and bananas. The volumes of these products exported in 1955 were respectively: 160,000 tons, 200,000 tons, and 30,000 tons. Archives Nationales d'Outre-Mer (ANOM), BIBECOL//10917, Giraud, 'La Politique Routière et ses Conséquences Économiques', in Giraud et. al., *Routes en Afrique Occidentale Française: Conférences Prononcées à Dakar le 28 Novembre 1956* (April 1957), 21 (hereinafter: Giraud, 'La Politique Routière et ses Conséquences').

A road network to move goods

After the Second World War, as part of a large programme of infrastructure development in the colonies, the metropole committed to invest in transport systems in general, and road development in particular. Funds for transport development came from the Caisse Centrale de la France d'Outre-Mer (CCFOM) and mostly from the Fonds d'Investissement pour le Développement Économique et Social des Territoires d'Outre-Mer (FIDES), both of which were created in the post-war period.[59] The FIDES financed the two development plans that covered the periods from 1948 to 1953 and 1953 to 1959, which had the objective of modernising 'Afrique noire' and Madagascar by offering the loans necessary to fund large projects that included support for agricultural production, mining, research, and transport development.[60] Transport was attributed a significant portion of the funding since it was considered the key element to ensure the exports of raw materials and the imports of manufactures. From April 1946 to June 1951, of the 240 billion CFA francs spent by the FIDES and the CCFOM on development projects in all the overseas territories, 170 billion were destined to support transport programmes and social facilities (such as hospitals, schools, etc.); this corresponded to 70 per cent of total investment, of which 85 billion (i.e. 50 per cent) were spent exclusively on transport development.[61] Funds for transport development also came from general and local budgets, as well as from road funds (Fonds Routiers), which were created in several territories during this period with taxes to fuel consumption.[62] In FWA, in particular, from 1948 to 1959, about 11.6 billion CFA francs were spent on road development only, which corresponded to more than a third of the total money spent on development in the territory during the period.[63]

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[59] The CCFOM was in charge of issuing money and of financing social and economic development. After the independence of several colonies the Caisse was renamed the Caisse Centrale de Coopération Économique (CCCE) in 1958 and continued to provide funding, although lost its monetary role. After 1959 funds were also received from the Fonds Européen de Développement. For details on the FIDES see the ANOM website: http://anom.archivesnationales.culture.gouv.fr/ark:/61561/wu706hcy.num=20.q=routes+en+afrique+occidentale+ (04/06/2017)

[60] ANOM, 3TP/141, Plans d'Équipement, 1938-1951 (Afrique Occidentale Française: Routes), 'Texte Conférence Prononcée le 17-10-51 à la Société d'Encouragement pour l'Industrie Nationale par Monsieur Postel-Vinay, Directeur Général de la Caisse Centrale de la France d'Outre-Mer' (1951), 2 (hereinafter: ANOM 3TP/141, Plans d'Équipement, 1938-1951 (AOF: routes), 'Texte Conférence par Postel-Vinay').

[61] From October 1948 to December 1959, 1 CFA franc was the equivalent of 2 French francs. ANOM, 3TP/141, Plans d'Équipement, 1938-1951 (AOF: routes), 'Texte Conférence par Postel-Vinay', 2; Giraud and Millier, 'Routes à Faible Prix de Revient', 9, 26.

[62] FWA created a Road Fund in 1952-53. Bourdillon, *Les Ingénieurs des Ponts au Service de l'Afrique*, 402.

[63] In FWA, the total investment on social and economic development from 1948 to 1959 was of about 30 billion CFA. Most of this money came from the two FIDES plans, which consisted of 22.9 billion CFA francs, 20 per cent of which was spent on road development (i.e. 4.6 billion CFA francs). To this sum were added about 7 billion CFA francs from the Fonds Routier and the general and local budgets. Giraud,

With these funds FWA developed a policy of building and maintaining low-cost roads (or 'routes économiques'). Broadly speaking, low-cost construction in FWA acquired the same meaning noted in Chapter 1.[64] However, in FWA, the term 'low-cost' was also used as a tool to seek funding. Since the costs for building roads in FWA were high, road programmes attracted a lot of criticism, and it was only reluctantly that loans were attributed. Therefore, in the presentation of road projects, expenses were brought down to the minimum to fit the definition of the low-cost road, term that seems to have been used to designate *all* road projects in the overseas territories.[65]

In the 1950s, roads carried more freight than railways in FWA.[66] For instance, in Ivory Coast in 1951, an average of 63 per cent of the two most important products of the territory (coffee and cacao) were transported by lorry and not by rail.[67] In 1957, it was estimated that approximately 2,200 million ton-km of goods were transported in FWA (including exports and imports), and most of this volume was moved by road (i.e. 1,400 million ton-km), while only about a fourth of the tonnage was carried by railway (see Graph 3.1).[68] Although this could suggest that roads were competing with railways, it seems that roads were (at least part of them) feeding the railways.[69] The Gouverneur Général of FWA had to approve of the creation of any transport company for either passengers or goods and it appears that this measure avoided the competition between both kinds of methods, especially in the case where roads were parallel to the railways.[70]

'La Politique Routière et ses Conséquences', 6-7 ; Giraud and Millier, 'Routes à Faible Prix de Revient', 7.

64 In particular, allowing for high speeds was not a concern: 'in under-developed countries in overseas territories… there is no need… for an alignment suitable for high average speeds which would entail expensive earthworks', instead roads had to be 'adapted to the nature of the terrain' and the 'alignment must be modified to eliminate any difficulties in plan or in longitudinal profile which might interfere with the use of the roads by heavy lorries, since the employment of these lorries is essential to bring about a reduction in transport costs'. J. Chauchoy and R. Lantenois, 'Section 1: Construction and Maintenance, Question 3, Low Cost Roads, French West Africa', in *PIARC* (Istanbul, 1955), 27 (hereainfter: Chauchoy and Lantenois, 'Low Cost Roads, FWA').

65 With, it seems, the exception of Northern Africa. 'Aussi, afin de poursuivre notre programme, a-t-il fallu toujours rogner sur la dépense et essayer de justifier le terme de "routes économiques", vocable par lequel on désignait toutes les réalisations routières dans les Territoires d'Outre-Mer', Giraud, 'La Politique Routière et ses Conséquences', 12.

66 From 1951 to 1957, the volume of exports in FWA almost doubled, going from about 856,000 tons to 1,512,611 tons; while imports remained rather stable in comparison (going from 1,471,000 tons to 1,721,149 tons). The figures available exclude iron and bauxite exports. Giraud and Millier, 'Routes à Faible Prix de Revient', 4.

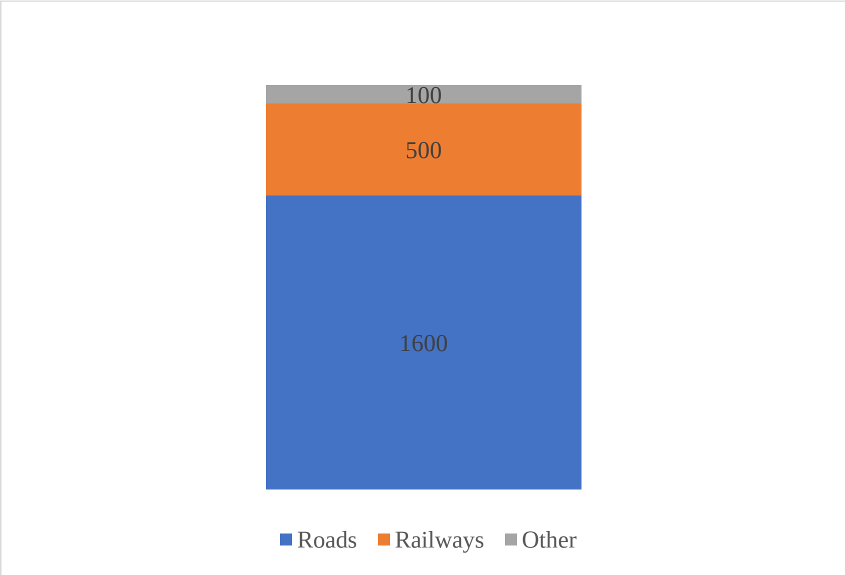
67 67 per cent of coffee exports and 58 per cent of cacao exports were transported by road. ANOM, 3TP/78, Afrique Occidentale Française, 1953-1957, République Française, *Afrique Occidentale Française*, 'Plan 1953-1957 d'Équipement Routier de l'Afrique Occidentale Française', 2.

68 Giraud and Millier, 'Routes à Faible Prix de Revient', 4.

69 Giraud and Millier, 'Routes à Faible Prix de Revient', 4.

70 ANOM 3TP/141, Plans d'Équipement, 1938-1951 (Afrique Occidentale Française: Routes), Sécrétariat d'État aux Colonies, Inspection Générale des Travaux Publics. *L'équipement Économique des Colonies*

Graph 3.1 Distribution of volume carried by transportation method in French West Africa in 1957 (in millions of ton-km)



Source: Giraud and Millier, 'Routes à Faible Prix de Revient', 4.

Road construction costs were usually high, and although they varied enormously, some averages can be presented. In the early 1950s, the construction of an earth road (nine metres road bed, improved with local materials and including earthworks and small engineering structures) would usually cost about 2 to 3 million CFA francs per km, while the construction of a bitumen new road could cost from 4 to 8 million depending on the amount of earthworks needed.[71] Due to the high costs of bitumen surfaces, only urban streets and heavily trafficked roads (more than 100 vehicles per day) were paved.[72] The high cost of paving directed attention towards the development of methods for laying light surfaces in order to make earth roads more resistant to heavy traffic. These surfaces included light bitumen surfacings containing varied quantities of bitumen (also called 'carpets', see Chapter 2), and other methods that used mixtures of sand, cement or other materials. These methods were considered low-cost only because their price was lower than that of any other type of

Françaises, Afrique Occidentale Française – Les Routes, (s.d.), 12; Giraud and Millier, 'Routes à Faible Prix de Revient', 12.

[71] In 1954, 1 million CFA francs was the equivalent of 5,714 USD. IBRD, 'Technical Report on the French West African Railways'; Chauchoy and Lantenois, 'Low Cost Roads, FWA', 27; M. Giraud, 'Prix de Revient des Travaux Routiers Entrepris au Sénégal', in *Revue Générale des Routes et des Aérodromes*, 23 (April 1953), 36.

[72] Urban traffic could be very heavy, as was the case on the road Abidjan-Port Boët (Ivory Coast) in 1956, which had traffic of 3,000 to 7,000 vehicles per day. Chauchoy and Lantenois, 'Low Cost Roads, FWA', 15; Anon. 'Problèmes Routiers et Circulation en Côte d'Ivoire', in *Revue Générale des Routes et des Aérodromes*, 26 (1956), 81.

pavement, but their actual cost was high.[73] In fact, by the mid-1950s most roads were not protected by a bituminous carpet and were thus extremely vulnerable to erosion and traffic.[74] In 1956, about a third of the network corresponded to earth tracks with little or no earthworks at all ('pistes').[75] The rest of the network consisted of roads, which means the construction involved earthworks (such as drainage or embankments), but even in this category the majority of the road length was not paved.[76]

Maintenance costs also weighed heavily on FWA's finances. In the early 1950s, the ideal expenditure to maintain an earth road was about 60,000 to 80,000 CFA francs per km per year, and that sum could increase to 800,000 or 1,000,000 CFA francs per km if a light bituminous surfacing was provided.[77] Yet, the maintenance budget of FWA at the time was of only about 20,000 to 50,000 CFA francs per km.[78] This was particularly challenging because maintenance and improvements were meant to be funded with local budgets, while metropole money (such as FIDES funds) was to be used exclusively for new construction.[79]

The high construction and maintenance costs in FWA resulted from varied factors. First, the natural environment presented a significant challenge. From extremely dry areas, to zones of tropical rainfall, conditions were often very different even within the same territory. The need for bridges and important drainage works considerably increased the prices of road projects, and inadequate works would render maintenance almost impossible.[80] Heavy rains also had to be taken into account in the planning of the works as often a year would only include about 200 working days due to climate conditions.[81] In dry areas or seasons, corrugation was one of the most challenging problems that roads faced (see Chapter 2). In addition, the long distances and the low density of the population made very expensive the transport of workers, materials, equipment, and other supplies (such as spare parts and food for the workers).[82]

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[73] 'The need for treating the soil to a depth of at least some 8 to 10 centimetres, the fact that a travel-mixer must be employed for the work, and the quantities of binder which have to be incorporated, combine to give a final cost which is high', Chauchoy and Lantenois, 'Low Cost Roads, FWA', 24.
[74] Chauchoy and Lantenois, 'Low Cost Roads, FWA', 25.
[75] Annexe F. ANOM 3TP/78, Afrique Occidentale Française, 1953-1957, République Française, *Afrique Occidentale Française, Sommaire Conditions Économiques* (1956), 30 (hereinafter: AOF, *Sommaire Conditions Économiques*).
[76] AOF, *Sommaire Conditions Économiques*, 30.
[77] Lantenois, 'Construction of Roads in Thinly Populated or Under-Developed Countries', 10.
[78] Lantenois, 'Construction of Roads in Thinly Populated or Under-Developed Countries', 5.
[79] ANOM, 3TP/85, Projets Routiers Divers en Afrique 1950-1957, Fonds Européen, 'Renforcement Route Togo-Nigeria, Sous-Dossier Technique' (ca. 1955), 2.
[80] Some projects could need many bridges; depending on the difficulties found in the foundations a reinforced concrete bridge with a roadway of 3.50 m-wide could cost on average about 250,000 to 350,000 CFA per metre of structure. Chauchoy and Lantenois, 'Low Cost Roads, FWA', 27.
[81] Lantenois, 'Construction of Roads in Thinly Populated or Under-Developed Countries', 8.
[82] Chauchoy and Lantenois, 'Low Cost Roads, FWA', 25.

The cost of road works also depended on other factors, such as the availability and cost of labour and equipment, the cost of fuel, lubricant and other supplies, and of course, on the condition and technical specifications of the road. In particular, engineers constantly complained about the scarcity and high cost of labour in French sub-Saharan Africa after the abolition of forced labour in 1946.[83] In the post-war period, migration towards Anglophone African countries (and especially to the Gold Coast) also contributed to the increasingly high cost of manual labour.[84] Given the scarcity of labour, engineers in FWA were considering employing women for heavy construction and maintenance works in the early 1950s, as some engineers in other colonies did (in particular in Gabon, French Equatorial Africa).[85]

Growing traffic was also a decisive factor. The construction and expansion of maritime ports contributed greatly to the increasing traffic.[86] From 1930 to the mid-1950s, the number of vehicles in use multiplied by ten reaching almost 70,000 in 1956.[87] In 1956, Senegal and Ivory Coast were by far the territories with the largest vehicle fleet (see Table 3.1).[88] Another sign of the increase in the use of motor vehicles was the rise of fuel consumption. In fact, it more than tripled from 1950 to 1957, passing from 109,400 m^3 in 1950 to 367,055 m^3 in 1970.[89] What made this increase in traffic particularly damaging was its weight. Although in Ivory Coast, for instance, most goods were moved in light trucks (2 to 5 tons), traffic on some unpaved roads could reach 1,000 vehicles per day in 1959.[90] In addition, traffic norms

[83] Recent research points out that despite the formal abolition of forced labour some practices continued, see Introduction note 77.
[84] Migration to look for employment in, for example, gold mines or cocoa plantations became permanent instead of seasonal after the Second World War, due to economic difficulties resulting from the conflict and also to the abolition of forced labour. Joanna Warson, 'Protecting Empire from Without: Francophone African Migrant Workers, British West Africa and French Efforts to Maintain Power in Africa, 1945-1960', in Andrew W.M. Smith and Chris Jeppesen (eds.), *Britain, France and the Decolonization of Africa: Future Imperfect* (London, 2017), 158.
[85] Women extracted and transported materials, such as gravel from riverbeds. Gilbert Meunier, 'Un Problème, le Réseau des Routes du Gabon', in *Revue Générale des Routes et des Aérodromes,* 23 (June 1953), 39. According to Freed, in the 1920s and 1930s the use of female labour in French central Africa was less about the scarcity of labour than about cultural practices that saw the work with earth as an exclusively female task. Freed, 'Networks of (Colonial) Power', 215.
[86] Bourdillon, *Les Ingénieurs des Ponts au Service de l'Afrique*, 381.
[87] In January 1930 there were in total approximately 6,700 vehicles in use, by January 1952 there were about 40,200 and by December 1956 there were 69,928 vehicles in circulation. International Chamber of Commerce, *A Statistical Survey of World Highway Transport* (Paris, 1931), 13; International Road Federation (IRF), *World Road Statistics, Revised Second Edition* (London, 1953), 16; AOF, *Sommaire Conditions Économiques*, 32.
[88] AOF, *Sommaire Conditions Économiques*, 32.
[89] M. Giraud, 'Programme Routier de l'Afrique Occidentale Française', in *Revue Générale des Routes et des Aérodromes*, 321 (Oct. 1958), 84.
[90] The majority of roads carried from 40 to 300 vehicles per day, but some earth roads carried 400 to vehicles per day, reaching peaks of 1,000 vehicles per day. Tracks usually carried up to 40 vehicles a day. Giraud and Millier, 'Routes à Faible Prix de Revient', 26.

followed the metropolitan Code de la Route, which meant that 13 ton-axle load lorries were permitted, the circulation of which was extremely damaging, if less frequent.[91]

Table 3.1 Motor vehicle fleet in French West Africa in December 1956

Territory	**Motor vehicles**
Senegal	24,409
Sudan	992
Mauritania	5,607
Guiney	7,932
Ivory Coast	20,451
Dahomey	3,159
Niger	4,649
Upper Volta	2,729
Total French West Africa	69,928

Source: ANOM 3TP/78, Afrique Occidentale Française, 1953-1957, République Française, *Afrique Occidentale Française, Sommaire Conditions Économiques* (1956), 32.

Many engineers considered this combination of heavy lorries with low-cost roads a contradictory policy.[92] Transport costs on bad surfaces could sometimes be double the price of those on a well-maintained surface. For instance, in Senegal in 1953, it was considered that transport cost 9 to 10 CFA francs per ton-km on bitumen roads, 12 to 15 CFA francs on good earth roads, and 18 to 20 CFA francs on bad earth roads and tracks.[93]

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[91] ANOM, BIB SOM D/BR/2360, Bureau Central d'Études pour les Équipements d'Outre-Mer, *Recommandations du Comité Technique Crée pour l'Étude Générale des Routes Économiques* (Paris, 1951), 15; Chauchoy and Lantenois, 'Low Cost Roads, FWA', 13.
[92] Giraud and Millier, 'Routes à Faible Prix de Revient', 14.
[93] In 1952 CFA francs. Giraud, 'Prix de Revient des Travaux Routiers Entrepris au Sénégal', 22.

The new mechanised maintenance regimes

Engineers in FWA established intensive regimes of maintenance that were meant to progressively improve roads over time, a process the engineers called ‘progressive maintenance’ – the same concept described in Chapter 1 as ‘stage construction’.[94] Schemes of progressive maintenance were established by graduates of the École des Ponts since at least 1950, and increasing experience and equipment were gained throughout the decade.[95]

These new maintenance regimes relied heavily on modern earth-moving machinery. Mechanisation started in a significant way after the Second World War, justified by the scarcity and cost of manual labour (and not by issues with the quality or speed of manual work).[96] The impression that American machinery had made on French engineers during the conflict was also an influential factor (see Chapter 2).[97] Although in FWA French lorries (Citroën, Renault) were common, the majority of earth-moving machinery came from the US, and above all, from Caterpillar, which was the brand that dominated the market.[98] If the D8 Caterpillar tractor was ubiquitous, the motor-grader was considered the key element of any construction or maintenance project (see Figure 3.2). Motor-graders could work maintaining about 500 km of road per year, and while in 1951 there were 50 in the whole of FWA, the numbers were expected to double quickly.[99] These machines were expensive. For instance, in 1953, in Dakar, a motor-grader Caterpillar 12 cost 3,700,000 CFA francs, a D8 cost 4,400,000 CFA francs and a Letourneau scraper 3,350,000 CFA francs, which, together with a Marion 1,5 Cv shovel (16,000,000 CFA francs), made 80 per cent of the total cost of machinery for a road construction project.[100]

Figure 3.2 Maintenance of earth road with motor-grader, 1952[101]

[94] Lantenois, ‘Construction of Roads in Thinly Populated or Under-Developed Countries’, 9.
[95] Bourdillon, *Les Ingénieurs des Ponts au Service de l’Afrique*, 381, 401.
[96] This was the case of manual maintenance, whose cost was ‘the main reason for which the system had become obsolete’. Lantenois, ‘Construction of Roads in Thinly Populated or Under-Developed Countries’, 5.
[97] See also Bourdillon, *Les Ingénieurs des Ponts au Service de l’Afrique*, 565.
[98] Each maintenance and construction unit was usually conformed by one or two tractors, a bulldozer, a scraper, a roller, a motor-grader, and a few lorries. A list of machinery in construction and maintenance units can be found in Annexe G.
[99] Lantenois, ‘Construction of Roads in Thinly Populated or Under-Developed Countries’, 8.
[100] Giraud, ‘Prix de Revient des Travaux Routiers Entrepris au Sénégal’, 23.
[101] This picture is from French Cameroon but it illustrates the type of heavy machinery used in FWA in the same period.

[Picture removed from ethesis version on copyright grounds]

Source : Roger Delahaye, 'La Construction de la Route Douala-Edéa', in *Revue Générale des Routes et des Aérodromes*, 22 (Nov. 1952), 71, 79.

Many machines were modified to respond to local conditions. The solutions adopted to deal with corrugations are a good example. As mentioned in Chapter 2, there were no machines specially designed to deal with this problem, so different alternatives were employed. Three of these were: 'planing' machines (parallel or inclined blades mounted on a chassis and drawn by a pneumatically-tyred tractor), trains of pneumatic tyres (mounted on a fixed chassis or coupled to chains and drawn by a tractor or lorry), and light motor-graders.[102] The efficacy of each method was still being tested so there was no consensus on which one obtained better results. Often, the choice of method was more related to the availability of equipment than on technical superiority. For instance, in Niger (following the example of the Company on the Gao-Tessalit road in the Sahara) a device was built consisting of a 'kind of drag formed by rails connected to each other in the shape of a V'; in Senegal a similar device was built 'formed by a kind of plane with scraper blade and saw teeth in front', each of these artefacts was drawn by 35-40 hp tractor.[103] Despite these efforts, corrugations could reappear after no longer than a week from reshaping, as was the case in the Bamako-Segou road, which carried about 100 to 200 vehicles a day (half of which were 5 ton lorries).[104]

Regimes of mechanised maintenance were put in place across FWA but the one adopted in Ivory Coast in the early 1950s seems to have been one of the most developed and

[102] Chauchoy and Lantenois, 'Low Cost Roads, FWA', 27.
[103] Lantenois, 'Construction of Roads in Thinly Populated or Under-Developed Countries', 6.
[104] Lantenois, 'Construction of Roads in Thinly Populated or Under-Developed Countries', 6.

successful.[105] The work was divided between three main groups: the road sectors ('secteurs routiers'), the machine teams ('équipes d'engins') and the reloading groups ('groupe de rechargement'). Road sectors consisted of groups of 20 workers under the authority of a leader; these groups were in charge of doing manual ordinary maintenance of about 120 km of roads and 200 km of tracks.[106] The machines teams had the responsibility of doing more significant improvements and reshaping the roads when necessary. They would usually have at their disposal two to four motor-graders.[107] Finally, the reloading groups were in charge of transporting materials to refill the roads whenever the rolling surface was insufficient.[108] In total, in 1959 there were 24 motor-graders doing work on over 7,000 km of road with a frequency of 7 to 20 days on each road.[109] The good conditions of the machines were permanently controlled by flying teams of mechanics that periodically visited the sites or made special trips in case important repairs were needed.[110] Each machine was checked every three weeks, which shows the importance of maintenance in all stages of road development.[111]

By the late 1950s, after ten years of working with the mechanised maintenance teams, the method was considered very successful. Heavy rains were not a threat for the roads anymore and it seemed that dust was the only persistent problem on the network.[112] The maintenance regime allowed unpaved roads to bear peaks of 1,000 vehicles per day.[113] The few bitumen roads, on the other hand, were carrying timber articulated lorries with axle loads surpassing the permitted 13 tons per axle.[114] Yves Meau, an engineer who transferred from Mali to Ivory Coast in 1959 remembers having been impressed upon his arrival with the territory's well-structured and well-equipped maintenance services, efficacious organisation of mechanised works, and excellent road structures.[115]

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105 Maintenance was the responsibility of the Service des Travaux Publics and the chiefs of the Circonscriptions Administratives. The Subdivision of Mechanical Equipment (Subdivision d'Outillage Méchanique, SOM) provided the machinery for the Service des Travaux Publics, and also ensured the maintenance and inspection of the plant. ANOM, BIB ECOL//10917, J. Millier, 'L'Effort Routier en Côte d'Ivoire', in Giraud et. al., *Routes en Afrique Occidentale Française: Conférences Prononcées à Dakar le 28 Novembre 1956* (April 1957), 23 (hereainfter: Millier, 'L'Effort Routier en Côte d'Ivoire').
106 Giraud and Millier, 'Routes à Faible Prix de Revient', 26.
107 Giraud and Millier, 'Routes à Faible Prix de Revient', 26.
108 Because of rain and dust, the road levels frequently went down and materials to put it back to the usual level were necessary. Millier, 'L'Effort Routier en Côte d'Ivoire', 23.
109 Giraud and Millier, 'Routes à Faible Prix de Revient', 28.
110 Millier, 'L'Effort Routier en Côte d'Ivoire', 23.
111 Millier, 'L'Effort Routier en Côte d'Ivoire', 23.
112 Giraud and Millier, 'Routes à Faible Prix de Revient', 26.
113 Giraud and Millier, 'Routes à Faible Prix de Revient', 26.
114 Bourdillon, *Les Ingénieurs des Ponts au Service de l'Afrique*, 422.
115 Bourdillon, *Les Ingénieurs des Ponts au Service de l'Afrique*, 382.

In fact, by 1959, engineers in Ivory Coast believed they had discovered potentially universal concepts for maintaining roads in 'under-developed' countries everywhere, with the variations environmental conditions would demand.[116] The first one was the need to intervene before the road was deformed either by rain or by traffic, as it would render the works cheaper. The second one was periodic maintenance, although the frequency of maintenance varied according to the type of road: rural tracks should be maintained every six months, an earth road bearing about 100 to 300 vehicles per day every fourteen days, and some stretches with heavy traffic or particularly difficult environmental conditions every seven days. In addition, maintenance and improvement works were to be light and fast, keeping significant reshaping to a minimum. Ditches were to be avoided because the topography of the country did not make them absolutely necessary, and this would allow for faster interventions. However, the camber of the road was rather steep (five per cent) to guarantee the drainage of water – despite the fact that it could be uncomfortable for the drivers. It is worth noting here that both ditches and road cambers were built explicitly with the objective of facilitating maintenance, but had to be thought early on, even before actual construction, during the process of design. Furthermore, maintenance teams worked all year long, even during heavy rains, which was only possible because the interventions were superficial and therefore did not require major earthworks. Finally, the team leaders for major works were chosen carefully: the engineer needed at least one year of experience following closely the work of maintenance units before being put in charge.

In general, the maintenance regimes of the 1950s seem to have contributed to the reduction of transport costs in FWA. Lorry tariffs diminished from 18-20 francs per ton-km in 1950, to 8 francs or less in 1957.[117] Road conditions were most likely linked to this reduction. By 1956, although a small percentage of roads were paved (i.e. less than 5 per cent on average in Senegal, Dahomey, Ivory Coast and Sudan), almost 50 per cent of the road network in these territories was all-weather.[118] The engineers also noted that the imports of vehicle spare parts had risen at a slower pace than fuel consumption in the same period, which they interpreted as a consequence of the improvement of the circulation conditions.[119]

[116] This paragraph is based on: Giraud and Millier, 'Routes à Faible Prix de Revient', 26-28.
[117] It seems these prices were given in nominal value. In 1959, 1 CFA franc was equivalent to 2 metropolitan francs. Giraud and Millier, 'Routes à Faible Prix de Revient', 9, 26.
[118] Giraud, 'La Politique Routière et ses Conséquences', 11.
[119] Giraud and Millier, 'Routes à Faible Prix de Revient', 9.

Conclusion

The study of road development in FWA and the Algerian Sahara in the 1950s has revealed similarities between the two cases. Both tell a story about roads crossing vast, largely uninhabited areas carrying increasingly heavier lorries. They also illustrate how roads acquired increasing importance as compared to railways. The central role of road transport explains the significant efforts undertaken by both private firms and the public administration to support road development. These comprised the investment on road projects and research, the mechanisation of construction and maintenance, the use of materials laboratories, and the realisation of organisational and administrative changes, amongst others.

The case of the Algerian Sahara stands out because of the abundant resources available and the emphasis that the construction of paved roads acquired during this period. It is also an example of how 'old' local practices continued to be used, while new knowledge was produced to serve the pioneering endeavour of building motorable roads in this environmental context. This case also illustrates that the use of laboratory tests for road construction became essential, but not sufficient, as experience and time were considered necessary to confirm all findings.

Maintenance appears in both cases as a determinant factor since it conditioned transport costs and made the difference between a passable road and a bad investment. Hence, maintenance was a concern from the moment the road characteristics were being designed, to the moment in which the road had to serve a rising traffic, passing through the construction process. The case of FWA is remarkable for its success, as the mechanised maintenance schemes established, especially in Ivory Coast, allowed low-cost roads to carry rising freight traffic under good conditions.

Chapter 4 Roads as railways: Argentina's road development, 1930-1970

Argentina started the twentieth century a wealthy country, and the industrialisation policies of the 1930s and the post-war period managed to produce substantive economic growth. The country's wealth was reflected in its large transport system. By the middle of the twentieth century, with about 42,800 km of railways, Argentina had the most extensive railway network in Latin America, and one of the largest in the world.[1] Outside of Europe and North America, only India rivalled Argentina's rail length.[2] The country also had a large total road network, as by 1952 it was longer than that of Great Britain, Italy or Spain at the time.[3] Argentina's vehicle fleet was the second largest in the region at the time, behind that of Brazil.[4]

However, from 1950 to 1970, roads struggled to keep up with the rising transport demands, which is perhaps not surprising given that the replacement of railways by roads as the main freight transport method, a process that had started in the 1930s, was consolidated in the two decades after the Second World War. In fact, by the late 1960s, despite the road network still consisting of almost 40 per cent unpaved surfaces, it carried twice as much freight than railways (in ton-km).[5] Neither railway nor road engineers welcomed this shift, as it was commonly considered that railways were the best method to carry goods over long distances. And yet, in 1968, while railways carried about 20 million tons originating, roads carried over 260 million tons originating.[6]

This chapter argues that Argentina's national road network was able to withstand rising lorry traffic in the post-war period mostly due to maintenance and improvement works, as well as to the shift from building mostly seasonal to all-weather roads. I also suggest that the success of these developments was facilitated by the experience that road authorities and construction firms had acquired in the interwar years.

[1] International Road Federation (IRF), *World Road Statistics, Revised Second Edition* (London, 1953), 19-21.
[2] Excluding Australia and the Eastern Bloc. India had about 54,900 km of railways in 1952. IRF, *World Road Statistics, Revised Second Edition* (London, 1953), 20.
[3] See Annexe A.
[4] International Bank for Reconstruction and Development (IBRD), International Development Association (IDA), 'Appraisal of a Highway Project Argentina' (Washington D.C., March 1971), 3 (hereinafter: IBRD, 'Appraisal of a Highway Project Argentina, 1971').
[5] See Annexe L and below. Dirección Nacional de Vialidad (DNV), *Panorama Vial de la República Argentina. Situación Actual de la Dirección Nacional de Vialidad* (Buenos Aires, 1970), 27 (hereinafter: DNV, *Panorama Vial*).
[6] IBRD, IDA, 'Appraisal of a First Railway Project Argentine Railways' (Washington D.C., March 1971), Table 1 (hereinafter: IBRD, 'Appraisal of a First Railway Project Argentina, 1971').

This chapter starts by briefly presenting the Argentinian road building experience of the 1930s and 1940s, highlighting the influence of the American model in the construction of low-cost (and concrete) roads. This first section shows that the use of materials laboratories and road-building machinery started in the 1930s and suggests that this early modernisation gave the emerging national construction industry and the Dirección Nacional de Vialidad (DNV), the authority in charge of national road development, experience which would prove valuable to road programmes after the war. The second section of the chapter highlights the challenges that the DNV had to face from 1950 to 1970, when roads became the main carriers of goods by land. The difficulties the DNV had to tackle came from both the rising number of lorries and the scarcity of funds that resulted from the state's inability to adapt tax legislation to accommodate growing inflation, and to its prioritisation of the interests of the state-owned energy company Yacimientos Petrolíferos Fiscales (YPF). This section ends by laying out the different policies adopted by the DNV during the period, emphasising that the pace of new construction radically decreased after 1943. Instead, a combination of routine maintenance, small improvements, and a shift from building mostly unimproved earth roads to building almost exclusively all-weather roads were the measures that allowed roads to carry such traffic increases. The final section of the chapter shows how these developments built on the modernisation efforts of the previous two decades. I point out that although road engineering in other countries seem to have had some influence on Argentinian engineers, and in particular Mexico and Brazil, the American model was the main example for these professionals throughout the period.

It is important to stress Argentina's wealth: in 1913, Argentina had the tenth highest level of income per capita in the world, and by the late 1920s, the country's GDP per capita was the highest in the region (and not far from that of the US).[7] As a response to the Great Depression, Argentina (like many other Latin American countries, and Colombia in particular) adopted an inward-looking model of economic development that generated a considerable industrial base which was further developed after the Second World War.[8] Argentina's industrialisation efforts in the 1950s and 1960s were so successful that it warranted the country the label of 'semi-industrialised', alongside Mexico and Brazil.[9] By 1970, Argentina still had the highest GDP per capita in Latin America (1,055 US dollars per capita in 1970 prices), and the country's GDP growth rate (at constant prices) had increased from 2.8 per cent in 1950-1960

[7] Victor Bulmer-Thomas, *The Economic History of Latin America since Independence*, 3rd ed. (New York, 2014), 161, Appendix 4, 528.
[8] Bulmer-Thomas, *The Economic History of Latin America*, 253.
[9] Bulmer-Thomas, *The Economic History of Latin America*, 303.

to 4.4 per cent in 1961-1970.[10] Nevertheless, Argentina's national industry remained largely dependent on the imports of capital and intermediate goods throughout the period (and especially of machinery and equipment), which caused severe balance-of-payment problems, as well as exchange-rate instability, and inflation.[11] These economic problems were influenced by political instability; in fact, the governments of Perón (1946-1955), Frondizi (1958-1962), and Illia (1963-1966) were all cut short by military coups, and were followed by a military dictatorship led by Onganía (1966-1970).[12]

Argentina had a large and relatively robust transport system by the early 1950s. This system consisted of railways built mostly from the mid-nineteenth century until about the 1920s (mostly British-owned until their nationalisation, which was completed in 1951), and of roads resulting from an accelerated pace of construction that took place in the 1930s and early 1940s.[13] From the 1930s onwards, compared to the rapid expansion of the road network, the growth of the railway mileage was very slow.[14] In addition, the railways suffered from a rising deficit and a deterioration of service that made them unable to compete with the developing lorry transport.[15] The fact that roads were carrying a larger proportion of goods than railways is all the more remarkable given the long distances they had to cross, as in Argentina distances of about 300 km were considered medium and only hauls of about 1,000 km were considered to be long.

The Argentinian case is therefore particular because, as a relatively wealthy Latin American country, it nevertheless depended on low-cost roads, and unimproved unpaved roads

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[10] As Bulmer-Thomas argues, in general, the rate of growth of Latin American GDP compared favourably with other developing countries during the period (as it was higher than that of East Asia) and was faster than the rate of growth in the developed countries. Bulmer-Thomas, *The Economic History of Latin America*, Table 9.4, 330-36.

[11] Bulmer-Thomas, *The Economic History of Latin America*, 303-06. See also Luis Alberto Romero, *A History of Argentina in the Twentieth Century* (Pennsylvania, 2013) and Annexe H.

[12] There were also a few de facto interim presidents in-between these administrations. About the relationship between political and economic instability in Argentina during the period see Guido di Tella and Rudiger Dornbusch (eds.), *The Political Economy of Argentina, 1946-83* (London, 1989).

[13] In 1971, the Staff Appraisal of a highway loan project at the World Bank characterised Argentina's road network in the mid-1940s as 'one of the finest in the world'. IBRD, 'Appraisal of a Highway Project Argentina, 1971', 3; H.R. Stones, *British Railways in Argentina, 1860-1948* (Bromley, 1993), 3.

[14] The length of the railway network grew from about 38,300 km in 1930 to about 43,700 km in 1965. In contrast, from 1934 to 1969, over 35,000 km of new national roads were built (without taking into account provincial or municipal roads). *Directory of Railway Officials & Year Book 1966-1967* (London, 1967), 572; DNV, *Memoria 1963-1966* (Buenos Aires, s.d.), 13; Biblioteca Nacional Mariano Moreno (Argentina), Departamento de Archivos, Fondo Centro de Estudios Nacionales, Subfondo Arturo Frondizi (hereinafter: AR-BNMM-ARCH-CEN), 03.4.4.4 Caja UC 108. Naciones Unidas Consejo Económico y Social, Comisión Económica Para América Latina, *Los Problemas del Transporte de la Argentina y la Orientación de sus Soluciones* (Santiago de Chile, 1958), 79; DNV, *Memoria 1968-1969* (Buenos Aires, s.d.), 10.

[15] Mario J. López and Jorge E. Waddell (eds.), *Nueva Historia del Ferrocarril en la Argentina. 150 Años de Política Ferroviaria* (Buenos Aires, 2007), 157-208.

continued to play a role until the late 1960s – in a way they do not seem to have done in the developed world at the time. In addition, Argentina's position at the beginning of the century also facilitated the country's early adoption of modern machinery and methods. Unlike the examples presented in the previous chapter (and Chapter 5), Argentina's adaptation of American approaches started before the Second World War. However, just as the case of FWA, road development in Argentina after the war is a story about the crucial role that maintenance and improvement acquired to allow the growing circulation of freight – although to a much larger scale. Argentinian railways did not benefit from the protection their counterparts had in FWA and suffered from the competition of the growing trucking industry (which was, in turn, taking advantage of the declining railway services).

The history of road development in Argentina has attracted considerable attention from its infancy in the first decades of the century, until the end of the second Juan Domingo Perón administration in 1955. Authors such as Melina Piglia and Anahí Ballent have focused on the relationship between the state and private associations (and in particular automobile clubs) in the first half of the twentieth century arguing that these private actors influenced the country's road policy by promoting the use of automobiles for racing but also for tourism, an activity that was increasingly seen as economically important for the nation.[16] Some of the crucial material consequences of the clubs' rhetoric have also been noted, such as the creation of a vast network of service stations across the territory as a result of the association between the Automóvil Club Argentino (ACA) and YPF.[17] However, while these authors mention the importance of low-cost roads, they do not explain the meaning or the implications of this construction method. In addition, even though the role of roads in the substitution of imports and the development of agriculture has been mentioned, by concentrating on the promotion of tourism, the historiography has largely neglected the consequences of rising lorry traffic.

Valeria Gruschetsky studied the influence of American road engineering and administrative organisation in Argentina from 1920 to 1940.[18] According to her, the experience of the US was referenced in engineering conferences and publications, and its influence was visible in

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[16] Anahí Ballent, 'Kilómetro Cero: La Construcción del Universo Simbólico del Camino en la Argentina de los Años Treinta', in *Boletín del Instituto de Historia Argentina y Americana Dr. Emilio Ravignani*, no. 27 (June 2005), 107–37. Piglia also highlights the part that automobile clubs played in the establishment of road transport as a public issue and adds that under the Perón administration the ACA managed to remain close to the state in great part because it succeeded in creating an image of itself as a technical, apolitical body. Melina Piglia, *Autos, Rutas y Turismo: El Automóvil Club Argentino y el Estado* (Buenos Aires, 2014).

[17] Energy company founded in 1922.

[18] Valeria Gruschetsky, 'Saberes Sin Fronteras. La Vialidad Norteamericana como Modelo de la Dirección Nacional de Vialidad, 1920-1940', in Mariano Ben Plotkin, and Eduardo A. Zimmermann (eds.) *Los Saberes del Estado* (Buenos Aires, 2012), 185-212.

the way the DNV was set up and in the establishment of taxes for road users to fund road development (as opposed to tolls).[19] Nevertheless, while Gruschetsky stated that the adaptation of American knowledge was key for the construction of the low-cost road network during the period, she did not go into detail about what this entailed and she did not delve into the role that Argentinian engineering played in the region.

The main sources used in this chapter are the *Memorias* and varied technical publications from the DNV. The journals from the DNV and the Asociación Argentina de Carreteras (AAC) were also valuable sources to understand the Argentinian engineers' position in relation to national and international road-related developments. Finally, staff appraisal reports of road projects with the World Bank, as well as studies commissioned to foreign consultants, were vital to access some general data and assessments about road development during the period. This was particularly useful due to the fact that limited DNV data is available today, partly because data collection was inconsistent throughout the period, but also because political instability (during and after the period of study) resulted in the loss of significant material, making it difficult to grasp a general picture of road development and to evaluate the results of the varied measures taken.

The experience of the 1930s and 1940s

Low-cost roads and the influence of American road engineering

From 1933 to 1947, about 28,500 km of national roads were built, of which only 10 per cent were paved.[20] Figure 4.1 shows that from 1930 to 1943 the number of kilometres built per year reached peaks that the country would not see again throughout the period. This figure also indicates that in this period of accelerated construction, most of the new roads were seasonal with dirt surfaces ('tierra'). Historians Ballent and Gruschetsky have characterised these unpaved roads as 'low-cost' ('bajo costo') because they were the result of the prioritisation of the extension of road length to the detriment of the quality of the surface.[21] According to them, this policy had the objective of promoting agricultural production, creating jobs, and contributing to national integration by covering as much of the vast national

[19] Canada and New Zealand road financing were also influential. Gruschetsky, 'Saberes Sin Fronteras', 189.

[20] DNV, *Memoria 1936* (Buenos Aires, s.d.), 131; República Argentina, Ministry of Public Works and Services, Transportation Planning Group, *A Long Range Transportation Plan* (Buenos Aires, 1962), Main Report, 43 (hereinafter: TPG, *A Long Range Transportation Plan*).

[21] Ballent, 'Kilómetro Cero', 107–37; Gruschetsky, 'Saberes Sin Fronteras', 185-212.

territory as possible in a short amount of time.[22] In 1931, Argentina had an automobile density per inhabitant comparable to that of France and Great Britain (1 automobile per 26 inhabitants), and a motor vehicle density in relation to the road network of about 95 vehicles per kilometre of road (almost four times higher than that of the US).[23] However, traffic was concentrated around the capital, and by 1935 Justiniano Allende Posse (director of the DNV from 1932 to 1938) considered that low traffic density was one of the main problems the DNV had to confront.[24] In 1950, railways were still carrying more freight than roads by far (in ton-km).[25]

Figure 4.1 Length of new roads built per type of surface in Argentina, 1933-1970 (km)

[Picture removed from ethesis version on copyright grounds]

Note: In red, all-weather roads; in yellow, dirt roads; and in black total of national roads.

Source: DNV, *Panorama Vial*, Fig. 7.

[22] Ballent argues that despite the influence that automobile clubs exerted in the construction of roads geared towards tourism from the mid-1930s onwards (and despite the construction of certain large projects designed to satisfy urban transport demands), the director of the DNV from 1932 to 1938 maintained a discourse that favoured unpaved low-cost roads. Ballent, 'Kilómetro Cero', 128; Gruschetsky, 'Saberes Sin Fronteras', 197.

[23] Ballent, 'Kilómetro Cero', 111.

[24] DNV, *Memoria 1935*, Speech by Allende Posse, 38, quoted in Ballent, 'Kilómetro Cero', 117.

[25] See Graph 4.1. IBRD, 'Appraisal of a First Railway Project Argentina, 1971', Table 2.

The evidence seems to suggest that low-cost construction was indeed adopted in Argentina in the 1930s – not least because of the funds restrictions brought about by the Depression. Although further research is needed on the construction methods employed in this period, explicit references to low-cost roads ('caminos de bajo costo') were being made as early as 1936.[26] The term was used to refer to roads that were built minimising costs, deferring the construction of a paved surface, and following particular modern methods that were being developed by the US at the time (see Chapter 2). These methods consisted of the use of laboratory tests and soil mechanics on the one hand, and of road-building machinery on the other. Although it is unclear what percentage of roads were built with these modern methods, American techniques were known and adopted since at least the mid-1930s. In 1936, for example, under the direction of an American engineer, Noel S. Anderson, several experimental stretches of stabilised low-cost roads were built in the provinces of Buenos Aires, Córdoba, and Santiago del Estero after conducting laboratory studies of the soils, aggregates (such as rock) and bituminous materials that were employed in the works.[27] In fact, the Argentinian engineer Juan Carlos Bustos (who worked at the DNV, reported on these road experiments, and taught university classes on low-cost construction in the 1930s) insisted on the fact that learning how to recognise materials, predict their behaviour, and manipulate them in order to guarantee the stability of the road was central to the definition of a low-cost road.[28] Bustos also connected low-cost construction with the use of modern machinery, as mechanisation increased the speed of road works and reduced labour costs.[29]

Connections with the US resulted in a clear understanding of the significance of US low-cost road building methods. In 1936, the president of the DNV, the engineer Justiniano Allende Posse, travelled to the US with two technicians to learn about the road building experiments that were being carried out there.[30] This was considered a great opportunity – in 1936 the DNV saw the US as an 'enormous experimental laboratory', where the investment of

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[26] See Juan Carlos Bustos, 'Caminos de Bajo Costo', in DNV, *Publicaciones Técnicas Vol. 5,* 2ª ed. (Buenos Aires, 1936), 128; DNV, *Memoria 1936*, 9; Mario San Miguel, 'La Construcción de Obras Básicas y su Relación con los Firmes de Bajo Costo', in *Caminos*, 27 (Jul.-Aug. 1938), 63-73.
[27] In 1952 Noel S. Anderson was a District Engineer of the BPR in the Physical Research Branch, Research Division (Columbia, S.C.). These experiments were also possible due to the growing production of bituminous materials, making available different types of mixtures that could suit various traffic, materials, and weather conditions. Bustos, 'Caminos de Bajo Costo'. For staff of the BPR see: United States Civil Service Commission, *Official Register of the United States* (Washington D.C., 1952), 405-456.
[28] For him, determining what materials would allow to entrust the stability of the road (in great part or completely) to the soil that bore it was at the very centre of the definition of what a low-cost road was. Bustos, 'Caminos de Bajo Costo', 75, 79.
[29] Bustos pointed out that mechanisation allowed the completion of more than 1 km per day and demanded only a few cents per square meter in labour costs. Bustos, 'Caminos de Bajo Costo', 79.
[30] The exact place of the visit was not specified. DNV, *Memoria 1936*, 9.

hundreds of millions of dollars allowed the performance of experiments leading to precise conclusions about all types of works.[31] For the DNV, this trip confirmed the importance of promoting low-cost roads, which they understood to mean focusing on guaranteeing transport continuity while leaving to one side more expensive works deemed not strictly necessary.[32] In 1938, the DNV engineer Mario San Miguel published an article explaining methods of building low-cost roads in *Caminos* (the official journal of the DNV) and his bibliography was almost entirely American.[33]

Another example of the influence of the US in the 1930s is concrete construction. During the interwar years, the US was the main referent for concrete road construction in the world, and by the middle of the century it was the country with the largest mileage of concrete roads in the world.[34] It is difficult to measure the length of concrete construction in Argentina because the data did not distinguish between concrete and bitumen surfaces; they were usually both classified in the category 'superior pavement'.[35] However, concrete (with and without reinforcement) was being used in road construction since the first half of the century. For instance, in 1936, the stretch of the Ruta 9 between Rosario and the Capital Federal was paved with reinforced concrete due to the heavy traffic it carried.[36] The engineering professor Eduardo Arenas stated in 1951 that a great part of the concrete construction undertaken in the first half of the century was, however, unnecessary at the time.[37] For him, the first long concrete road built in the country, in 1927 (from Morón to Luján), was in large part the result

[31] DNV, *Memoria 1936*, 9.
[32] Bustos noted that although low-cost construction required low initial investment, it was not clear that this type of construction was cheaper in the long-term if all costs were taken into account (construction, maintenance, reconstruction and operation). Bustos, 'Caminos de Bajo Costo', 128; DNV, *Memoria 1936*, 9.
[33] Out of seven references only two were not American publications, they were Argentinian (and one of the latter was an article describing a trip to the US that two Argentinian engineers undertook). The American references included the Bulletin of the University of Illinois, the 1937 Convention Proceeding of the American Road Builders Association, and an article by R. Proctor in the American magazine *Engineering News-Record*. San Miguel, 'La Construcción de Obras Básicas', 73.
[34] Peter J Hughil, 'Good Roads and the Automobile in the United States 1880-1929', in *Geographical Review*, 72 (1982), 342; A.R. Collins and D.R. Sharp, 'The Design and Construction of Concrete Roads Overseas', in *Proceedings of the Institution of Civil Engineers*, 9 (Jan. 1958), 24.
[35] The DNV distinguished between 'superior pavement' (i.e. concrete, bituminous carpets, bituminous macadam, etc.) and 'economical pavement' (i.e. stabilised base, light bituminous treatment, and other improvements).
[36] DNV, *Memoria 1936*, 131.
[37] Eduardo Arenas was a professor of road engineering at the Universidad Nacional de Buenos Aires in the mid-1950s. Eduardo Arenas, 'Algunos Problemas Técnicos de Nuestra Vialidad, Conferencia en Córdoba, 31 de Julio de 1951' in Cámara Argentina de la Construcción, *Algunos Problemas Técnicos de Nuestra Vialidad* (Buenos Aires, 1952), 59-62 (hereinafter: Arenas, 'Algunos Problemas Técnicos de Nuestra Vialidad'); American Association of State Highway Officials (AASHO), *Análisis del Beneficio de los Usuarios en el Mejoramiento de Caminos, Parte 1*, Traducido y Editado por la Asociación Argentina de Carreteras (Buenos Aires, 1955), 1 (hereinafter: AASHO, *Análisis del Beneficio de los Usuarios*).

of the intense desire to build a resistant surface with a method that was becoming very popular in the US.[38] During the 1940s, concrete construction continued and given the difficulty of finding steel during wartime, non-reinforced concrete became the preferred method (Figure 4.2).[39] Although some of the concrete stretches built in the 1930s and 1940s were suffering from poor maintenance conditions in the 1950s and 1960s, many of them were still in operation two decades after being built (Figure 4.3).[40]

Figure 4.2 Photo of a construction site of a reinforced concrete road in Argentina, 1943

[Picture removed from ethesis version on copyright grounds]

Source: DNV, *Memoria 1943* (Buenos Aires, s.d.), 92.

Figure 4.3 Advertisement from the Argentinian Institute of Portland Cement, 1955

[38] He did not specify whose desire this was, but it is likely that both engineers and the government wanted to adopt this technique since it was considered very advanced at the time. ‘No tengo inconveniente alguno en declarar que ese proyecto fue elaborado bajo la presión de un doble temor: el que derivaba de la falta de experiencia – pues en el país no la había de ninguna clase sobre el tema — y el que provenía del deseo intenso de propiciar con una obra sólida y duradera de generalización de un tipo de calzada que en Estados Unidos, espejo donde comenzábamos a mirarnos, gozaba ya de grandes simpatías’. Arenas, ‘Algunos Problemas Técnicos de Nuestra Vialidad’, 61.

[39] In 1943, some of the most important concrete surfaces in execution were: Medoza-Villavicencio (Ruta 7 - Mendoza), Rosario-Santa Teresa (Ruta 178-Santa Fe), Rio Salado-Las Flores km 25 (Ruta 3-Buenos Aires). DNV, *Memoria 1943* (Buenos Aires, s.d.), 103-104.

[40] About concrete roads needing maintenance and repairs see: DNV, *Memoria 1950* (Buenos Aires, s.d.), 115; DNV, *Memoria 1959-1962* (Buenos Aires, s.d.), 33; Arenas, ‘Algunos Problemas Técnicos de Nuestra Vialidad’, 62.

[Picture removed from ethesis version on copyright grounds]

Source: Instituto del Cemento Portland Argentino, 'Carretera de Santa Fe a Rosario, Después de 24 Años de Uso', in *Caminos*, 153 (Nov. 1955), 33.

As early as the 1930s, Argentinian engineers were conscious of the need to adapt American approaches to local conditions. Although Argentinian engineers were aware of the results of various experiments carried out in the US (such as those carried out at different universities), Argentinian engineering professors taught their students to conduct their own tests.[41] And even if American methods and norms (such as those of the Bureau of Public Roads, BPR) were used to conduct soil tests, for example, engineers and contractors were expected to adapt the project and construction methods to the characteristics of the local materials.[42]

[41] San Miguel, 'La Construcción de Obras Básicas', 72-73.
[42] San Miguel, 'La Construcción de Obras Básicas', 63.

Institutional and private construction experience

The creation of the DNV in 1932 provided the country with an institution that coordinated large-scale operations and established a tax regime for road funding that was essential for road development throughout the century. The DNV was in charge of building some road projects (and of providing the necessary studies), supervising all construction, managing its plant and equipment at a national scale, and maintaining the national network.[43]

The DNV acquired valuable experience using materials laboratories early on. In the 1930s, the DNV even had its own specialised laboratories: physical and mechanical, chemical, and soils.[44] In 1937, these laboratories received over 1,800 samples of different materials such as concrete, cement, sand, bituminous materials, amongst others.[45] The tests were carried out before and during the execution of works, being an essential step in the process of planning and supervising road projects.[46] By the early 1940s, these facilities were also receiving samples from private firms and other governmental agencies (such as the Ministry of Agriculture).[47] Due to the high demand and aiming to increase the speed with which results were obtained, the DNV started building laboratories across the country, and by 1943 there were 21 in total.[48] Meanwhile, the DNV organised short courses for the technical staff of the provincial authorities with the aim of diffusing certain specialties, and in particular geology, asphaltic materials, bituminous treatments, and soil mechanics.[49] Geology was a field that grew in importance for the DNV due to the exploration of areas to find materials that could be used for road construction.[50] Given the wide range of applications of materials tests, laboratories were also being created outside the DNV, where road building was not the only research area – although it was one of the most active ones.[51] For instance, the province of Buenos Aires founded in 1942 the Laboratorio de Ensayo de Materiales e Investigaciones

[43] Since the early 1940s, the DNV's Department of Maintenance distributed its tasks between a Maintenance and a Construction Division. The tasks of the latter comprised the construction of airstrips and road reconstruction. However, the vast majority of construction was performed by private firms. DNV, *Memoria 1943*, 127-128.
[44] DNV, *Memoria 1937* (Buenos Aires, s.d.), 74.
[45] DNV, *Memoria 1937*, 74, 77.
[46] DNV, *Memoria 1937*, 74, 77.
[47] In 1943, for instance, the DNV carried out a study of soil stabilisation with asphalt in order to build underground grain deposits. The study was commissioned by the Grain Maintenance Commission of the Ministry of Agriculture. DNV, *Memoria 1943*, 146.
[48] DNV, *Memoria 1943*, 151.
[49] DNV, *Memoria 1943*, 151-152.
[50] DNV, *Memoria 1952-1953* (Buenos Aires, s.d.), 109.
[51] Anon., 'LEMIT: Un Instituto de Fama Universal', in *Caminos*, 225 (Nov. 1961).

Tecnológicas (LEMIT), whose coverage expanded from provincial projects to national and private research in the course of its first two decades of existence.[52]

Private firms also gained significant experience. Although the DNV carried out some minor construction projects, most of the roads were built by small firms of limited, but growing capacity. In 1932-39, there were about 120 road construction firms.[53] Funds scarcity and the difficulty of acquiring spare parts during the Second World War, added to the Peronist barriers to the imports of plant and equipment, considerably affected the work of these enterprises.[54] Therefore, by 1940-46 their number had diminished to 80.[55] Although in the late 1940s and 1950s Argentinian construction firms had relatively little capital available and their plant was considered old (and often obsolete), the experience that these firms acquired from the 1930s onwards seems to have been useful for the growth that the industry saw in the 1960s (see below).[56]

Institutional maintenance experience

The DNV also acquired important maintenance experience in this period. Maintenance included progressive improvements, managing ferries, placing and repairing traffic signs, planting trees and building fences.[57] The DNV's Department of Maintenance administered and distributed the budget and plant across the country according to the length of the network and the type of work required.[58] Despite the difficulty of acquiring machines and spare parts during the war, in the early 1940s the DNV had at its disposal a considerable number of machines, such as 345 graders, 88 motor-graders, 283 lorries, and 164 tractors (Figure 4.4).[59] Although the DNV sometimes hired private firms for maintenance works, it usually carried out all maintenance itself.[60] The DNV limited the number of maintenance contracts because

[52] Anon., 'LEMIT', 21.
[53] Luis de Carli, 'Aspectos Generales del Problema Vial, Conferencia en la Sede Central de la Cámara Argentina de la Construcción, 24 de Julio de 1951' in Cámara Argentina de la Construcción, *Algunos Problemas Técnicos de Nuestra Vialidad* (Buenos Aires, 1952), 35 (hereainafter: De Carli, 'Aspectos Generales del Problema Vial').
[54] De Carli, 'Aspectos Generales del Problema Vial', 35-36.
[55] De Carli, 'Aspectos Generales del Problema Vial', 35.
[56] This topic merits further research. Pedro Petriz, 'De una Política Vial Para el País', in *Carreteras*, n. 19 (Sept.-Dec. 1959), 13-14; AR-BNMM-ARCH-CEN, 03.4.4.4 Caja UC 108. Coverdale & Colpitts, Consulting Engineers, NEDECO Netherlands Engineering Consultants, RENARDET SAUTI Consulting Engineers, *Estudio de los Transportes Argentinos. Fase I. Volumen 1. Informe* (1960),160 (hereinafter: Coverdale & Colpitts et. al., *Estudio de los Transportes Argentinos*).
[57] DNV, *Memoria 1943*, 128.
[58] DNV, *Memoria 1943*, 131.
[59] The DNV also had 658 'conservadoras' (or 'maintainers') but I have not been able to find a description of what these were. DNV, *Memoria 1943*,131.
[60] In Catamarca private firms were hired for maintenance works with satisfactory results. In 1957, 15,000 km of unpaved provincial roads were being maintained this way. Anon. 'La Vialidad Provincial en Catamarca', in *Carreteras*, n. 11 (Jul.-Sept. 1957), 13.

of the intricacy and wide range of works needed, preferring to supervise the work directly.[61] The proportion of national roads that underwent consistent maintenance increased considerably from 1943 to 1950, going from 67 per cent to 82 per cent.[62]

Figure 4.4 Motor-grader used for road maintenance in Argentina, 1943

[Picture removed from ethesis version on copyright grounds]

Source: DNV, *Memoria 1943*, 92.

<u>Roads for goods</u>

The challenges of growing lorry traffic and scarce funds

Although in 1950 railways carried almost twice as many ton-km than roads, by the late 1960s the situation was very different (Graph 4.1). In fact, from 1961 onwards, lorries carried more ton-km than railways.[63] In 1968, roads transported more than double the ton-km than the railways did, which corresponded to about 68 per cent of the goods moved by land (excluding pipelines).[64] Lorries transported goods mostly in bulk. For instance, in the early 1960s, only

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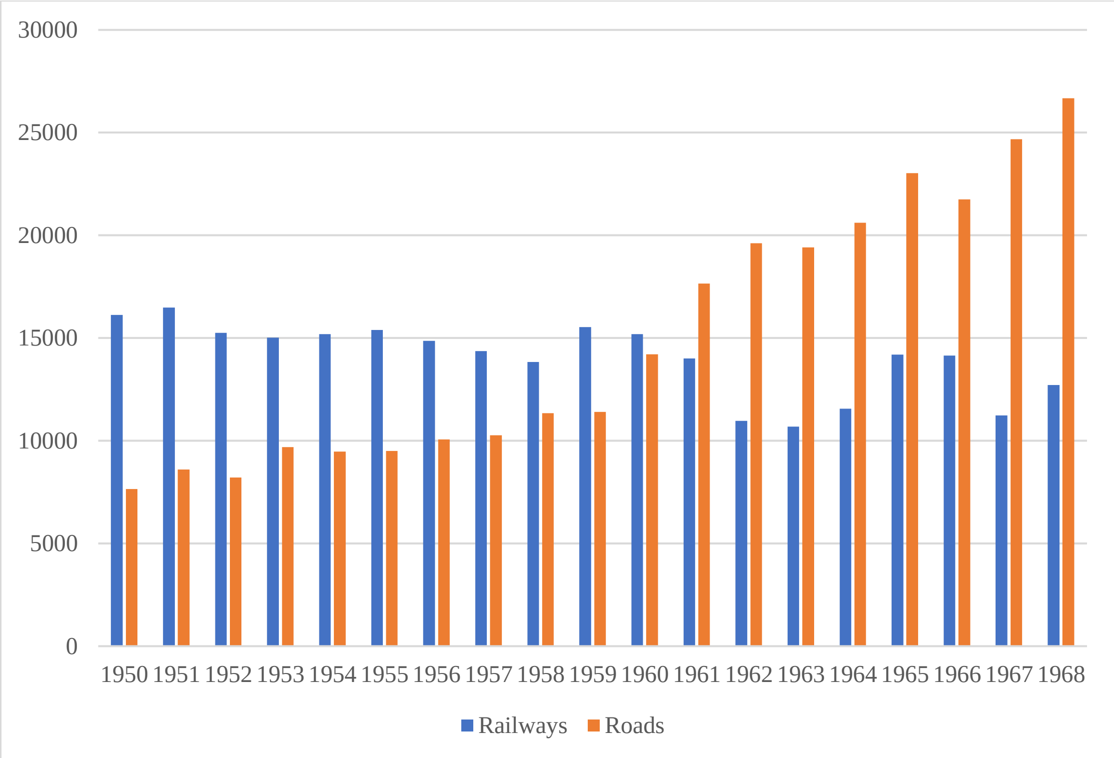
[61] TPG, *A Long Range Transportation Plan*, Appendix 2 Highways, 57.
[62] In 1943 the total length of the national network was 61,049 km and the length maintained was 41,069 km. DNV, *Memoria 1943*, 131; DNV, *Memoria 1950*.
[63] In 1961, roads carried over 17 million ton-km whereas railways moved 14 million ton-km. IBRD, 'Appraisal of a First Railway Project Argentina, 1971', Table 2.
[64] IBRD, 'Appraisal of a First Railway Project Argentina, 1971', Table 2.

about 16 per cent of the goods carried by lorry corresponded to small manufactured products.[65] The city of Buenos Aires was the destination of more than half the goods and the average haul distance was 300 to 400 km, although wine could travel for even longer distances.[66] In fact, the route from Mendoza to Buenos Aires (a little over 1,000 km) was the longest route bearing heavy traffic, mostly due to the production of wine and to what the Ministry of Public Works and Services qualified in 1962 as an inadequate railway service between the two areas.[67] Therefore, during the 1950s and 1960s, roads were carrying very heavy volumes of bulk goods over long distances – thus acting like railways.

Graph 4.1 Freight traffic by road and by railway in Argentina, 1950-1968 (millions of ton-km)



Source: IBRD, 'Appraisal of a First Railway Project Argentina, 1971', Table 2.

Roads were absorbing considerable traffic from the railways, which continuously reduced their share in the transport of goods during the period. Between 1950 and 1968, the railways'

[65] TPG, *A Long Range Transportation Plan*, Appendix 2 Highways, 25.
[66] TPG, *A Long Range Transportation Plan*, Appendix 2 Highways, 25.
[67] In 1962, apart from the roads in the vicinity of major urban centres (Buenos Aires, Córdoba, Rosario, Tucumán and Mendoza), and some stretches in zones of particular agricultural, mineral or industrial development, the majority of the network carried a few hundred vehicles per day, without reaching 1,000 vehicles. TPG, *A Long Range Transportation Plan*, Appendix 2 Highways, 25.

share of the total freight movement (in ton-km, including coastal shipping, river transport and pipelines) declined from 55 per cent to 17 per cent.[68] In contrast, during the same period, the roads' share increased from 26 to about 36 per cent.[69] The decline of the railway traffic was linked to the growing deterioration of the service. According to Jorge E. Waddell, the nationalisation of the railways (started in the 1930s and completed in 1951) did not prompt the establishment of an integrated transport policy which, added to the effects of the Great Depression and the limited investment in the maintenance and renovation of the system from the 1940s to the 1960s, put the railways at a disadvantage compared to the rapidly growing trucking industry.[70] Apart from a few isolated attempts to renew the stock, the state did not solve pressing structural problems (such as the duplication of lines or the growing operational deficit), and it did not launch any large railway projects during the period.[71] In 1959, the president of the DNV, the engineer Pedro Petriz, lamented the competition between roads and railways (that he also associated with the decline of the railway service), and he added that the shift from rail to road was not to be celebrated, as roads were suffering from heavier and denser traffic than they were designed to carry.[72]

The growth of lorry traffic in the period was indeed reflected in the increasing difficulty of maintaining the road network. The number of lorries almost tripled between 1954 and 1968 (Graph 4.2).[73] The capacity of the lorries was, however, not very large. In 1958, 89 per cent of the lorries had a total capacity of less than 4 tons (partly because 32 per cent of the lorries were pick-ups).[74] Nevertheless, the growing use of trailer and semi-trailers increased the capacity of each vehicle.[75] In addition, although the use of trailers distributed the loads over more axles, overloading was common. In the late 1950s, Argentina's vehicle weight regulations stated a maximum of 10 tons per axle (in line with American-manufactured lorries), but it was not uncommon to see loads of 13 tons per axle and more.[76] Overloading

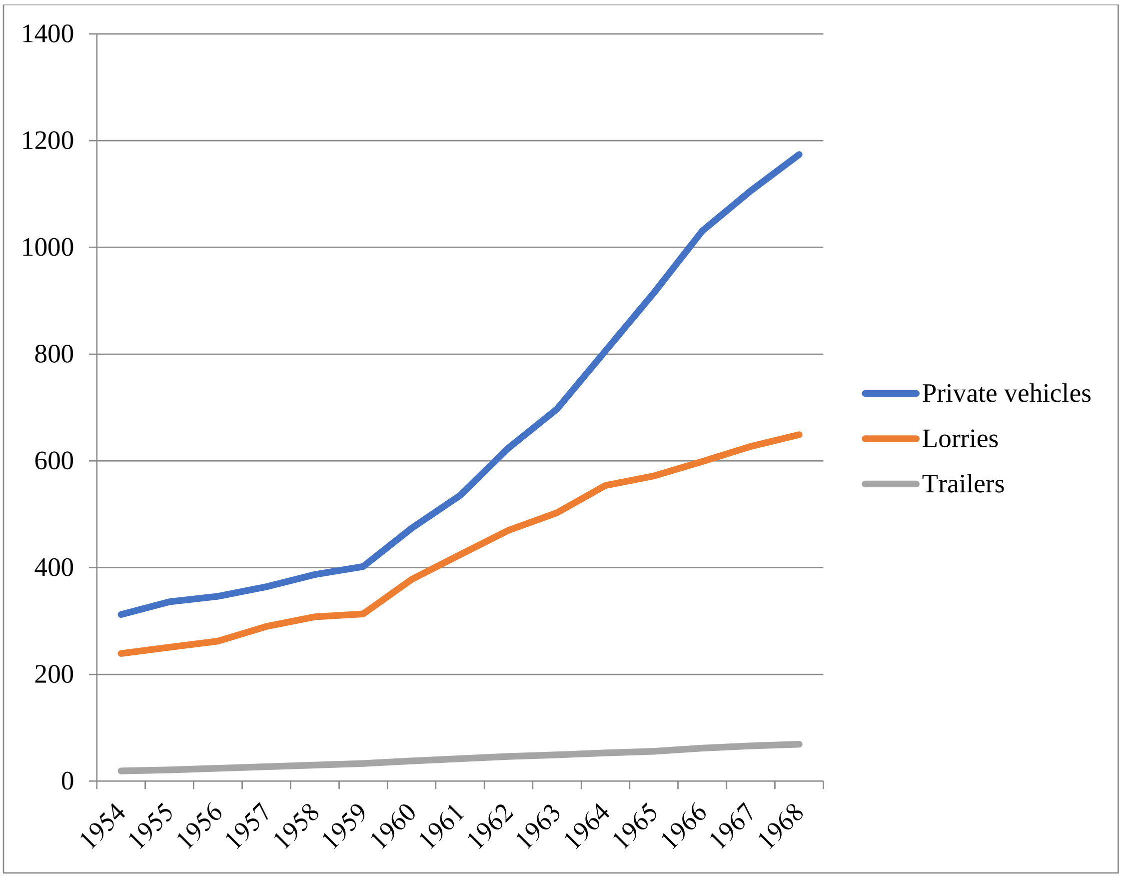
[68] IBRD, 'Appraisal of a First Railway Project Argentina, 1971', Table 2.
[69] In fact, the railways were the only transport method that decreased its share in the period, as the proportion of ton-km carried by river transport and coastal shipping combined increased from 17 to 36 per cent. IBRD, 'Appraisal of a First Railway Project Argentina, 1971', Table 2.
[70] López and Waddell, *Nueva Historia del Ferrocarril en la Argentina*, 157-208.
[71] López and Waddell, *Nueva Historia del Ferrocarril en la Argentina*, 157-208.
[72] Pedro Petriz, 'Fijación de una Política Caminera Nacional', in DNV, *Conferencias Sobre Temas Viales* (Buenos Aires, 1960), 28.
[73] Asociación Argentina de Carreteras (AAC), *Informe Sobre la Situación Vial Argentina Presentado al Ministerio de Economía de la Nación* (Buenos Aires, 1965), 14; IBRD, 'Appraisal of a Highway Construction and Maintenance Project, Argentina' (Washington D.C., June 1961), Annexe 1 (hereinafter: IBRD, 'Appraisal of a Highway Project Argentina, 1961').
[74] TPG, *A Long Range Transportation Plan*, Appendix 2 Highways, 23.
[75] A census carried out in 1961 confirmed that vehicles on rural roads had an average net load greater than 12 tons. TPG, *A Long Range Transportation Plan*, Appendix 2 Highways, 23.
[76] Anon., *Carreteras*, 11 (Jul.-Sept. 1957), 49.

was so ingrained in the practices of the lorry companies that they relied on it, also taking advantage of the lack of regulation of transport prices.[77] Meanwhile, conscious of the importance that road transport had acquired in the country, the DNV saw the sudden enforcement of weight norms as potentially damaging for the economy as they considered the railways unable to serve the demand this would generate.[78] By the late 1960s, the lack of traffic statistics does not allow for a complete picture of the problem of overloading, but the establishment of some survey stations from 1950 to 1968 confirmed that in some provinces about 90 per cent of the lorries were overloaded by 1970.[79]

Overloading generated a great number of problems for the DNV, especially because the network was mostly unpaved, even by the late 1960s. In 1969, about 44 per cent of the national road network was paved, 20 per cent had all-weather surfaces (i.e. unpaved improved surfaces), and the rest was either a track or an earth road without an improved surface.[80] Moreover, not only were most roads unpaved, the pavements built in previous decades had not been designed to carry the loads they were bearing and many required reconstruction.[81] Finally, as we will see below, the increase in lorry traffic also required the modification of general road geometrical characteristics (curves, gradients and width), which was a very expensive process.

Graph 4.2 Motor vehicle registration in Argentina, 1954-1968 (thousands)

[77] DNV, *Memoria 1957-1958* (Buenos Aires, s.d.), 63.
[78] Even if some engineers suggested it, in order to follow the example of the US at the time. Anon., *Carreteras*, 11 (Jul.-Sept. 1957), 49; DNV, *Memoria 1957-1958*, 63.
[79] These provinces were: Tucumán, Salta and Jujuy. DNV, *Panorama Vial*, 36.
[80] See Annexe L. DNV, *Panorama Vial*, Graph 14, 27.
[81] DNV, *Memoria 1957-1958*, 61.



Note: Buses and motorcycles not included.

Sources: Asociación Argentina de Carreteras, *Informe Sobre la Situación Vial Argentina Presentado al Ministerio de Economía de la Nación* (Buenos Aires, 1965), 14; IBRD, 'Appraisal of a Highway Construction and Maintenance Project, Argentina' (Washington D.C., June 1961), Annexe 1; IBRD, 'Appraisal of a Highway Project Argentina, 1971', Table 3.

In fact, despite the importance that road transport had acquired in relation to the railways, the DNV continuously listed the scarcity of funds as a major obstacle for its work during the period.[82] First, despite receiving substantial sums to fund road projects from different international agencies after 1961, Argentina struggled to produce enough funds to complete some of these projects.[83] For instance, the Argentinian state failed to cover its share of the

[82] Indeed, over the 1950s and 1960s, the DNV's *Memorias* often attributed the impossibility of completing its maintenance and improvements objectives to the lack of resources. DNV, *Memoria 1952-1953*, 13; DNV, *Memoria 1957-1958*, 3; DNV, *Memoria 1963-1966*, 1.

[83] Argentina received about 183.5 million USD from 1961 to 1969 for road projects (i.e. more than the amount Colombia received from the World Bank for road projects from 1950 to 1970, Chapter 5). The majority of this money (coming from the World Bank, the Export-Import Bank, USAID and the Inter-American Development Bank) was destined to road improvements, as well as consulting services, and the purchase of machinery for road maintenance. IBRD, 'Appraisal of a Highway Project Argentina, 1971', Annexe 1, 1-2.

first road project with the World Bank. Originally the Bank had lent 48.5 million USD for the first road project in 1961, but this amount was reduced to 32 million in 1965 due to, according to the Bank, the poor execution of the works, inadequate management of the project, ineffective use of the consultants, and lack of local funds.[84] It is likely that these were issues common to all road projects in Argentina during the time. Second, the state did not provide enough funds for the DNV to guarantee the completion of its own construction and maintenance programmes throughout the period, as we will see below. This was partly due to the rapid increase in costs. For example, maintenance costs per kilometre doubled from 1950 to 1954, going from about 1,000 to 2,160 pesos per year (pesos of 1950).[85] This rapid rise in maintenance costs was attributed to the growing intensity and weight of traffic, to the poor conditions of maintenance machinery, and to the higher costs of labour, materials, administration, etc., due to rising inflation.[86]

However, the limited availability of funds for road development appears to have been more an issue related to the collection and distribution of money than to actual scarcity. Argentina was indeed a relatively wealthy country, and roads seem to have been receiving a higher proportion of funds than railways. Between 1951 and 1960, for instance, roads received an average of 0.88 per cent of the GNP, while railways received 0.51 per cent, a significantly smaller amount, especially because railways were operated by the state after their nationalisation.[87] Nevertheless, the DNV considered roads had been underfunded since the mid-1930s. In 1970, the DNV compared the percentage of GDP spent on roads in different countries in 1963. It concluded that both developed and developing countries had spent on average 2.33 per cent of their GDP on roads that year (with the exception of certain island or 'semi-island' countries), and that, since Argentina had never dedicated more than 1.80 per cent of its GDP per year to road development from 1935 to 1970, the country had accumulated a considerable deficit in road investment over time.[88]

The availability of funds for road development was affected by the state's failure to adapt the tax legislation to the changing financial situation of the country, as well as to the state's

[84] IBRD, 'Appraisal of a Highway Project Argentina, 1971', 1.
[85] AR-BNMM-ARCH-CEN, 03.4.4.4 Caja UC 108. Naciones Unidas Consejo Económico y Social, Comisión Económica Para América Latina, *Los Problemas del Transporte de la Argentina y la Orientación de sus Soluciones* (Santiago de Chile, 1958), 286 (hereinafter: CEPAL, *Los Problemas del Transporte de la Argentina*).
[86] CEPAL, *Los Problemas del Transporte de la Argentina*, 286-287; TPG, *A Long Range Transportation Plan*, Appendix 2 Highways, 18. This process had already started in the late 1940s, see e.g. De Carli, 'Aspectos Generales del Problema Vial', 29.
[87] Consejo Nacional de Desarrollo, Luxardo, José D., *Los Caminos en la República Argentina* (1966), 48.
[88] The highest percentage was reached in 1970: 1.80 per cent. DNV, *Panorama Vial*, 46-52

prioritisation of YPF's interests. The most significant contribution to road development came from the taxes on gasoline, gas oil, and tyres.[89] However, rising prices were a constant preoccupation for the DNV because they made the real value of the tax revenues diminish.[90] To remedy this, in 1958, the taxes on gasoline and oil passed from being a specific value per litre to being a percentage of the retail price (i.e. 50 per cent in 1960-61).[91] However, already in 1961, the state changed the tax on fuel consumption (from being a percentage of the retail price to being a tax on 'retention') in order to support YPF, as the company was struggling to fund its operation and pay its tax contribution to road development.[92] This reduced the funds available for road development until the mid- and late-1960s (when the situation was modified with a special contribution from the National Treasury and the creation of an additional tax to naphtha consumption).[93]

The way in which tax collections were distributed also contributed to the limited availability of funds for the national road network. First, from 1950 to 1970 a significant proportion of the money that was destined to road development was directed towards the provincial network – as opposed to the national one, which consisted of the main trunk roads of the country (Figure 4.5).[94] Second, both the national energy fund (Fondo Nacional de Energía, created in 1947) and the General National Revenues received a considerable percentage of the tax on fuel consumption. For instance, in 1965, 52.5 per cent of the tax on fuel consumption was directed to the General Revenues and the Fondo Nacional de Energía.[95] It is important to note, however, that petroleum consumption was not limited to motor vehicle fuel but included, notably, industrial production. Nonetheless, the amounts collected from taxes exclusively related to the use of roads and motor vehicles were not fully directed to road development either. As the World Bank pointed out in 1971:

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89 From 1953 to 1960 these taxes passed from providing 55 per cent to almost 85 per cent of the National Road Fund's revenues. Other sources included taxes on vehicle sales, lubricants, etc. TPG, *A Long Range Transportation Plan*, Main Report, 76.

90 TPG, *A Long Range Transportation Plan*, Main Report, 76.

91 TPG, *A Long Range Transportation Plan*, Main Report, 76.

92 At the time, the retail price for gasoline, oil, and other petroleum fuels was fixed by the Secretary for Power and Fuels and it was composed of the tax for the National Road Fund and the 'retention' (i.e. the amount YPF retained to cover its costs, including exploitation, transport, and distribution). By changing the tax, the amount YPF paid to the Road Fund diminished considerably: for regular gasoline from m$n 2.70 to 1.74 per litre, and for oil from m$n 2.50 to 1.47 per litre. TPG, *A Long Range Transportation Plan*, Main Report, 76; DNV, *Panorama Vial*, 44.

93 These special measures were taken in 1967-69. Naphtha is a fuel derived from petroleum. DNV, *Panorama Vial*, 46.

94 DNV, *Panorama Vial*, 47.

95 Since the late 1940s the fund was receiving more than 50 per cent of the amounts collected from the tax to petroleum consumption. AAC, *Informe Sobre la Situación Vial*, 2; Juan S. Revuelta, 'La Red Nacional de Vialidad', in *Caminos*, 286 (Dec. 1966), 12-13; DNV, *Panorama Vial*, 17.

> Historically, total receipts from taxes on vehicle ownership and use have exceeded total expenditures on the highway system. The costs of investing in, administering and maintaining the highway system are met from a combination of earmarked fuel, tire and vehicle taxes and general revenues... The amount allocated *from* general revenues for highway expenditures has been less than the yield of the non-earmarked portion of taxes on vehicle ownership and use which goes *into* general revenues.[96]

Engineers often characterised the distribution of tax collections as unjustified and illegitimate.[97] Meanwhile, the energy sector resisted any changes to the tax legislation that would diminish its allocations.[98]

Figure 4.5 Graph of total investments in roads in Argentina (in millions of pesos constant value 1969)[99]

[Picture removed from ethesis version on copyright grounds]

Note: in black, national network; in blue, provincial network.

Source: DNV, *Panorama Vial*, Fig. 23, 47.

[96] The emphasis is made in the original text. IBRD, 'Appraisal of a Highway Project Argentina, 1971', 8.
[97] e.g. Juan S. Revuelta, 'La Red Nacional de Vialidad', in *Caminos*, 286 (Dec. 1966), 12-13.
[98] For instance, in 1958, President Frondizi struggled to convince the Secretary of Energy and Fuel (Meira) of the need to allocate more funds for road development. He argued that, unlike roads, the energy sector was more likely to receive funds from abroad. Anon., 'Profunda Conmoción de la Vialidad del País', in *Carreteras*, n. 56 (Dec. 1958), 1.
[99] Including construction of airports, buildings, etc.

What road policy?

The accelerated growth of road transport was not accompanied by a similar expansion of the road network length. Figure 4.1 shows that from building almost 3,500 km of road in 1943, Argentina went on to build less than 1,000 km per year from 1946 until 1962.[100] Although in 1967 almost 2,000 km of new road were built, on average from 1960 to 1969 no more than 900 km were built per year.[101] The fact that, by 1960, about 80 per cent of the roads had been built before 1945 had repercussions for road maintenance, as roads were not built to withstand such heavy traffic.[102] In addition, although the proportion of national roads that were paved increased from 10 per cent in 1950 to 44 per cent in 1969, a significant portion of the network remained unpaved throughout the period.[103]

Despite the lack of a long-term plan resulting from the country's political instability, certain trends can be identified in the measures undertaken by the DNV throughout the period in order to allow for the traffic increase. First, certain major improvements were continuously deferred. Already in the early 1950s, the need to adapt roads to the new lorries in circulation was a concern – as even concrete surfaces were failing under the growing loads.[104] Roads needed to be wider, the curves smoother and the surfaces more resistant. The lack of funds was, however, a major obstacle to carrying out all these improvements. As a result, the DNV postponed certain works to improve the roads' structural characteristics, such as the widening of the basic works in some routes and the reinforcement of roads' shoulders (often used as borrow pits).[105] Throughout the 1950s, and especially after 1957, the DNV did carry out expensive improvements, mostly renewing paved and improved surfaces, but also rebuilding bases and embankments in urgent cases.[106] Nevertheless, according to Petriz, these efforts were not only insufficient, they had been in vain.[107] He qualified them as ephemeral solutions that did nothing to solve structural damages that needed to be fixed urgently.[108] By 1960, only

[100] DNV, *Panorama Vial*, Fig. 7.
[101] DNV, *Panorama Vial*, Fig. 7.
[102] Pedro Petriz, 'Necesidades del País y Bases para el Desarrollo de la Obra Vial', in DNV, *Conferencias Sobre Temas Viales* (Buenos Aires, 1960), 18.
[103] See Annexe L. DNV, *Panorama Vial*, 27.
[104] The roads to access the Gran Buenos Aires were the most affected by this. For example, the Ruta 8 in the sections to access the Gran Buenos Aires was carrying more than 1,500 vehicles per day, more than any other access route. DNV, *Memoria 1950,* 115. See also De Carli, 'Aspectos Generales del Problema Vial', 27.
[105] DNV, *Memoria 1950*, 115.
[106] For instance, between 1953 and 1959, the DNV maintained 88 per cent of the concrete roads, 40 per cent of the asphalt surfaces, and 68 per cent of the bituminous treatments. DNV, *Memoria 1952-1953*, 12-13; DNV, *Memoria 1957-1958*, 31-37; Petriz, 'Necesidades del País', 19.
[107] 'Gastamos pues y gastamos mal'. Pedro Petriz, 'Necesidades del País y Bases para el Desarrollo de la Obra Vial', in DNV, *Conferencias Sobre Temas Viales* (Buenos Aires, 1960), 20.
[108] Petriz, 'Necesidades del País', 20.

one third of the national roads provided all-weather service and, with only two exceptions, none of the main roads in the country were paved over their entire length.[109]

Not even the 1961 World Bank loan (which provided assistance for the reconstruction and improvement of more than 2,500 km of roads, as well as for the purchase of road maintenance machinery and equipment for workshops) managed to alleviate the critical situation of the network.[110] Funds continued to be an obstacle for the upgrade of the width, the profile and the alignment of roads in the 1960s.[111] In 1965, for instance, the engineer Luis Apolinar Cardozo identified several deficiencies of earth roads in the Buenos Aires province that were difficult to solve. Many roads and tracks were the result of spontaneous use or of the division of land and were therefore not adequate for motor vehicles, especially in relation to curves.[112] For similar reasons, not only were roads sometimes too narrow for lorries, they also did not offer enough space for the movement of earth and other materials. This was particularly problematic since, to save money on transport costs, the areas along the roads were used as borrow pits, for which it was necessary to dig very deep ditches, making transit conditions dangerous.[113] In the late 1960s more plans were made to widen roads, fix their alignments and improve their surfaces. Although considerable progress was achieved, especially in 1967-69, by 1970 many roads still needed upgrading. The second road loan from the World Bank in 1971 had therefore the main objective of performing a range of improvements on more than 1,000 km of roads.[114]

Notwithstanding, in 1971, the World Bank considered the general maintenance conditions of the national network as good, especially in the provinces of Buenos Aires, Córdoba, Santa Fe, Mendoza and Tucumán.[115] In fact, although the DNV deferred some major upgrades, basic maintenance was carried out throughout the period. During the 1950s, an increasingly

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[109] The rest were impassable during rains and even for several days thereafter. This was particularly problematic for the transport of perishable goods. In addition to the national network, the provincial roads were in even worse conditions (about 130,000 km). IBRD, 'Appraisal of a Highway Project Argentina, 1961', 3-4.

[110] IBRD, 'Appraisal of a Highway Project Argentina, 1961', i.

[111] By 1962, reconstruction, widening and reinforcement were still a major concern. By 1966, the lack of funds continued to prevent the adaptation of roads to the heavy lorries. The DNV stated they were behind schedule for: extending the width of roads to 6 metres, improving the shoulders, performing basic maintenance of the main roads, amongst others. DNV, *Memoria 1959-1962*, 4; DNV, *Memoria 1963-1966*, 1.

[112] Luis Apolinar Cardozo, 'Sobre Mejoramiento y Consolidación de Caminos de Tierra', in Dirección de Vialidad, Ministerio de Obras Públicas, Provincia de Buenos Aires, *Séptimo Concurso de Trabajos Viales* (Oct. 1965), 233.

[113] Apolinar Cardozo, 'Sobre Mejoramiento y Consolidación de Caminos de Tierra', 233.

[114] The project also included the construction of some sections of freeway and money for consulting services for the supervision of construction works and the preparation of future projects. IBRD, 'Appraisal of a Highway Project Argentina, 1971', ii.

[115] IBRD, 'Appraisal of a Highway Project Argentina, 1971', 10.

high proportion of the DNV's budget was spent on maintenance, reaching a peak in 1955-57, when maintenance expenditure surpassed construction expenditure (Figure 4.6). Many challenges hindered the efficiency of these efforts. Apart from the heavy traffic and funds scarcity, since the majority of roads was built before 1945 and were not meant to carry such heavy traffic, maintenance was becoming increasingly challenging.[116] In addition, as previously mentioned, a large portion of the national network was unpaved throughout the period, and the proportion of all-weather roads was only 20 per cent in 1950, and less than 35 per cent in 1960; although by 1969 it had risen to about 64 per cent.[117] After the peak of maintenance investment in 1955-57, this type of work received a relatively steady amount of money until 1970 (Figure 4.6). This allowed for the employment of more than 6,000 labourers in the repair and restoration of roads.[118] However, given the rise in traffic and maintenance costs, these efforts of ordinary maintenance would probably have fallen short of keeping roads passable on their own.

Figure 4.6 Construction and maintenance expenditure of the Dirección Nacional de Vialidad, 1933-1970 (millions of pesos of 1971)

[Picture removed from ethesis version on copyright grounds]

[116] For instance, in 1957-58 the DNV stated there were about 7,800 km of national roads that demanded extraordinary maintenance work to remain passable. DNV, *Memoria 1957-1958*, 61; Bustos, 'Caminos de Bajo Costo'; Petriz, 'Necesidades del País', 18.
[117] See Annexe L. DNV, *Panorama Vial*, 27.
[118] For example, in 1963, 6,877 out of 9,824 labourers were employed on maintenance works. In 1966: 6,140 out of 9,137 workers. The rest were in charge of the workshops and warehouses, as well as ferry services (balsas), the planting of trees along the roads and of weighing vehicles (at the growing number of weighing stations). DNV, *Memoria 1963-1966*, 35.

Note: in grey, construction; in orange, maintenance.

Source: DNV, *Panorama Vial*, Fig. 20.

Indeed, in the 1960s, the DNV considerably increased its construction expenditure (Figure 4.6), contributing to the consolidation of the road network as the main land transport method in several ways. First, unlike the roads built in the 1930s and 1940s, the roads built after these decades were predominantly all-weather. Figure 4.1 clearly illustrates that after representing a small proportion of the newly built roads in the 1930s and 1940s, from 1950 onwards the vast majority of new construction was all-weather. This type of construction involved both paved surfaces (called 'superior' by the DNV), and 'economical' or 'improved' ones, i.e. those which had received some type of treatment (such as soil stabilisation) making earth surfaces more resistant to heavy rains and traffic (see also Chapter 2).[119] All-weather roads offered a considerably cheaper and more reliable service than seasonal ones. Operating a lorry on an unimproved earth road was almost twice as expensive than on a paved surface.[120] The growing length of paved roads therefore benefitted the lorry companies greatly, which were already taking advantage of the generally flat terrain and the lack of freight rates regulations.[121]

Second, not only were all-weather roads more resistant, they also made maintenance itself easier. Although the cost of maintaining a kilometre of paved or improved road was higher than that of a kilometre of a seasonal unimproved surface, the latter required special attention after rains and demanded a higher proportion of investment in machinery.[122] For example, in 1968, 49 per cent of the total cost of maintaining a kilometre of unimproved earth road was related to machinery and equipment, against 29 per cent in the case of a kilometre of paved

[119] About the DNV's pavement categories see above note 35.
[120] In 1962 the average cost of a three-axle lorry operation was: 14.7 pesos per km on a paved surface, 21.6 on gravel, and 26.9 on a dirt road. In 1971, on flat terrain, the cost of operating a goods vehicle was on average 8.5 US c/km on a paved road, 12.15 US c/km on a gravel surface and 18.5 US c/km on an earth road. The difference between flat and mountainous terrain was no more than 1 US c/km, which means that the surface was a more determinant factor than topography in terms of vehicle operation costs. TPG, *A Long Range Transportation Plan*, Main Report, 45; IBRD, 'Appraisal of a Highway Project Argentina, 1971', 36.
[121] In 1962, some provinces regulated the lorry freight rates of certain products (such as Buenos Aires and Santa Fe in the case of grain). IBRD, 'Appraisal of a Highway Project Argentina, 1971', 6; TPG, *A Long Range Transportation Plan*, Main Report, 50.
[122] In 1968, for example, the DNV spent on average 369 million pesos maintaining each kilometre of superior pavement, 237 and 214 million for every kilometre of intermediate and improved surface respectively, and 134 million for every kilometre of unimproved earth road. DNV, *Memoria 1968-1969*, 152.

road.[123] In addition, all-weather roads, just as heavy traffic, were mostly concentrated in the provinces of Buenos Aires, Córdoba, Mendoza and Santa Fe.[124] Therefore, the maintenance of these roads was relatively easy to coordinate, especially given that maintenance was managed by the central DNV office.[125] Finally, the length of the national road network actually diminished over time because many roads were transferred from the national to the provincial network, thus reducing the length the DNV was responsible for maintaining.[126]

Third, the DNV's category of 'construction' actually included some reconstruction and improvement works.[127] On average, from 1959 to 1969, about 30 per cent of construction works corresponded to reconstruction and improvement – a nonnegligible percentage.[128] Construction works also included paving existing roads. For instance, in 1962-63, out of 224 road works completed by the DNV, 16 consisted of paving existing roads, which corresponded to about 485 km of paved surfaces of different type (both superior and economical pavements).[129] On average, the DNV built about 300 km of paved surfaces on existing roads every year in 1963-66 and 1968-69 – although this represented only about 10 to 20 per cent of the length of works completed every year.[130]

Moreover, construction also included a portion of 'progressive improvements' since at least 1950.[131] The DNV gave no clear definition of what it understood by this term (sometimes called 'mejora progresiva' or 'conservación mejorativa'), but it seems it was related to the concept of upgradeability (Chapter 1). Progressive improvements comprised everything from major repairs of works of art, to surface stabilisation, paving, and even putting traffic signs along the roads.[132] What differentiated these works from other improvements was their

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[123] It corresponded to 28 per cent of the cost of total maintenance for roads of 'superior' pavements, and 30 per cent of the total maintenance cost of roads of 'intermediate' pavements. DNV, *Memoria 1968-1969*, 152.
[124] See Annexes I, J and K.
[125] In 1970 the DNV had the objective of starting a decentralisation process of maintenance works, leaving the central DNV office in charge of only the supervision of both maintenance and construction. DNV, *Panorama Vial*, 31.
[126] There is no data about the length of transferred roads.
[127] The rest of the 'construction' works consisted of basic works, paving and bridges. DNV, *Memoria 1963-1966*, 29.
[128] There is limited data for the period 1950-1959, but it seems the percentage was similar. DNV, *Memoria 1950*; DNV, *Memoria 1952-1953*; DNV, *Memoria 1957-1958*; DNV, *Memoria 1959-1962*, 15; DNV, *Memoria 1963-1966*, 15; DNV, *Memoria 1968-1969*, 14-15.
[129] The data does not distinguish between the different types of pavement done on existing roads. Thus, both superior and economical pavement are included in these figures. The figure for 1962-63 only includes 10 months in that year. From 1962 to 1964, the total number of road works was 373, of which 39 corresponded to paving existing roads, i.e. 861 km of new paved surfaces on existing roads. DNV, *Memoria 1963-1966*, 30.
[130] DNV, *Memoria 1963-1966*, 29; DNV, *Memoria 1968-1969*, 81, 88.
[131] DNV, *Memoria 1950*, 43.
[132] DNV, *Memoria 1950*, 43; DNV, *Memoria 1968-1969*, 16, 128.

explicit objective of gradually upgrading roads over time, thus protecting previous investments while deferring demanding works.[133] In the early 1950s, the DNV considered this a novel method, and one that blurred the limits between maintenance and construction: 'we should not establish a clear division between road maintenance and construction. On the contrary, between the two of them we must introduce and apply the concept of improving while maintaining'.[134] It is very difficult to measure the extent of the application of this method as the concept is only used in a few of the *Memorias* of the DNV. Nonetheless, it seems that the works in the category of progressive maintenance represented a significant proportion of construction works for at least some of the administrations in the period.[135] In general, from 1959 to 1969, works of progressive improvement corresponded on average to 10 per cent of the total kilometres of road works in execution.[136] Thus, despite the fact that certain upgrades were deferred during the 1950s and 1960s, road improvements were indeed taking place under both the maintenance and the construction works category, even if these remained a minority of the total invested on road works.

The DNV therefore responded to the growth of road transport demands from 1950 to 1970 by continuing basic maintenance, building all-weather roads, performing some progressive upgrades, and deferring certain expensive structural improvements. This combination seemed to have yielded good results, as by the early 1970s maintenance conditions were considered as generally good by the World Bank, and both the Bank and the DNV considered the length of the network as sufficient for the needs of the moment.[137] The DNV was concerned with some major issues, however, such as the fact that only 65 per cent of the national network was all-weather, compromising the quality and cost of the service.[138] Meanwhile, the Bank also estimated that there had been a tendency to provide stronger pavements than initially necessary (just as it did in the case of Colombia, Chapter 5).[139] Accordingly, the Bank

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133 'Como no es posible por ahora reconstruir esos tramos, se los ha mantenido con mejoras progresivas y conservación, impidiendo que el capital invertido en sus bases se pierda al desintegrarse éstas', DNV, *Memoria 1952-1953*, 13.

134 'No debemos establecer una línea divisoria neta entre las áreas de conservación de caminos y las de construcción. Por el contrario, entre ambas debemos introducir y aplicar el concepto de conservar mejorando', DNV, *Memoria 1952-1953*, 56.

135 In 1961 and 1962, for instance, out of the total amount spent by the DNV in the works that were completed those two years, progressive improvements were attributed more funds than basic works, reconstruction, and paving (i.e. 48 and 37 per cent of the total in 1961 and 1962 respectively). DNV, *Memoria 1959-1962*, 30-31.

136 DNV, *Memoria 1959-1962*, 15; DNV, *Memoria 1963-1966*, 15; DNV, *Memoria 1968-1969*, 14-15.

137 IBRD, 'Appraisal of a Highway Project Argentina, 1971', 10; DNV, *Panorama Vial*, 1, 64, 103.

138 DNV, *Panorama Vial*, 1, 64, 103.

139 IBRD, 'Appraisal of a Highway Project Argentina, 1971', 9.

suggested that in future, in order to optimise investments, stage construction principles should be applied (see Chapter 1).[140]

Building on previous efforts

The continuous American influence and the Argentinian engineers' position in the field

American road engineering approaches continued to be considered the main example to follow. As in the 1930s, DNV personnel frequently travelled to the US to observe the work of different Highway Departments and road laboratories. In the early 1950s, some scholarships were in place, in association with the International Road Federation (IRF), to offer specialisations and placements in the US to Argentinian engineers. For instance, in 1954, a competition amongst experienced road engineers was opened to select a candidate for a position in Colorado, with the condition of coming back to Argentina and working there for at least two years.[141] In 1961, the engineer Alberto Lanne, Chief of the Pavements Division of the DNV, went to the US for nine months to study the newest methods and machines used in road construction and maintenance. He visited a new Koehring machinery exhibition in Milwaukee, the laboratory of the Portland Cement Association in Illinois, he took a course on laboratory tests and techniques in California, and in Kansas he undertook research on compacting methods that he submitted to the BPR.[142]

Several translations of articles and books by different American associations, institutions and engineers were published in Argentina. For instance, in 1960, the AAC, with the supervision of engineers such as Eduardo Arenas and Enrique Humet, and with the approval of the American Association of Highway Officials (AASHO), translated an AASHO publication dating from 1952 on the subject of road improvements and their benefits for users.[143] This publication was meant to circulate amongst the members of the AAC free of charge.[144] The journal *Caminos* also published regularly translated articles from American, British and French road institutions or engineers. Amongst the sources featured journals such as *Contractors Record and Public Works Engineer* (UK), *Revue Générale des Routes et des*

[140] IBRD, 'Appraisal of a Highway Project Argentina, 1971', 9, Annexe 1.
[141] Roberto Gorostiaga, 'Aspectos de la Vialidad Argentina', in *Carreteras*, n. 1 (Jan.-Mar. 1955), 21.
[142] Alberto Lanne, 'Resultados de un Viaje de Estudio de Estados Unidos', in *Caminos*, 225 (Nov. 1961).
[143] Many other publications from the AASHO were translated with the permission of the association. See e.g. AAC, *Reunión Regional Sud-Americana de la International Road Federation* (Buenos Aires, 1960); AASHO, *Análisis del Beneficio de los Usuarios*, Introducción.
[144] In 1955 the AAC had about 500 associates. AASHO, *Análisis del Beneficio de los Usuarios*, Introducción; Gorostiaga, 'Aspectos de la Vialidad Argentina', 20.

Aérodromes (France), *Better Roads* (US) and the *Bulletin* of the IRF (US), as well as publications from Highway Departments from different American states such as Texas and California, and those of organisations such as the BPR, the Asphalt Institute (US), and the Association of Public Roads Functionaries (US).[145] Translations from American sources were the most numerous and revolved around topics such as mechanised maintenance, soil stabilisation and low-cost construction in general.[146] These translations were published without comments or adaptations, which means it was up to the reader to adapt the content to the local circumstances. In fact, that was a more or less explicit objective of the conferences and courses on road engineering since the 1930s: to provide the general knowledge necessary to interpret American publications and modify their suggestions according to the particular problems encountered.[147]

Foreign consultants were also important influences in Argentina, especially in the 1960s. In the late 1950s, the new government commissioned studies to evaluate the condition of the transport system; the most comprehensive was the *Long Range Transportation Plan for Argentina*, produced with the contribution of the United Nations Special Fund for Assistance, with the Bank for Reconstruction and Development acting as Executive Agency.[148] However, the extent to which the recommendations of foreign consultants were followed is difficult to trace. Given the political instability of the country many measures taken by one administration were often reversed by the following one, and despite the major importance of foreign studies in some respects (by, for example, providing traffic surveys), it seems the adoption of their suggestions was rather limited.[149]

In fact, broadly speaking, American approaches were sometimes difficult to adapt to the Argentinian context, not only because of environmental conditions (such as weather and soil characteristics), but also due to social and institutional differences, such as, for example,

[145] Prys Williams, 'Aspectos Económicos del Transporte Carretero', in *Caminos*, 153 (Nov. 1955); Roger Q. Spencer Jr., 'Prácticas de Mantenimiento de Carreteras', in *Caminos*, 175 (Sept. 1957); Anon., 'Estabilización de Suelos y Agregados', in *Caminos*, 209 (Jul. 1960); Anon., 'Un Distrito Rural Encuentra Manera de Obtener Buenos Caminos a un Costo Reducido', in *Caminos*, 195 (May 1959); H.A. Radzikowski, 'Requisitos en los Equipos de Construcción y Mantenimiento de Carreteras', in *Caminos*, 193 (May 1959); Harry J. McGregor, 'Nuestro Transporte Caminero', in *Caminos*, 155 (Jan. 1956); Dirección de Vialidad, Ministerio de Obras Públicas, Provincia de Buenos Aires, *La Estabilización de los Suelos por Medio del Cemento*, *Publicación N. 18* (1962).
[146] Spencer Jr., 'Prácticas de Mantenimiento de Carreteras'; Anon., 'Estabilización de Suelos y Agregados'; Anon., 'Un Distrito Rural Encuentra Manera de Obtener Buenos Caminos a un Costo Reducido'; Radzikowski, 'Requisitos en los Equipos'.
[147] The engineer J. Carlos Bustos made this explicit in 1936. Bustos, 'Caminos de Bajo Costo', 75.
[148] TPG, *A Long Range Transportation Plan*, Main Report, i. Other studies were CEPAL, *Los Problemas del Transporte de la Argentina*; Coverdale & Colpitts et. al., *Estudio de los Transportes Argentinos*.
[149] See e.g. in relation to roads that should replace railways, very limited adoption of the closure of lines that the long range transportation plan suggested. TPG, *A Long Range Transportation Plan*, Main Report.

traffic regulations and the feasibility of enforcing them.[150] In addition, sometimes the lack of data in Argentina made the adaptation of American approaches impossible. For instance, in 1954, the journal of the AAC quoted statistics from the US to discuss the problem of road user safety, whereas for Argentina it was only possible to make vague statements claiming road safety was also a challenge.[151]

Technical influence from other Latin American countries seems to have been relatively limited. Argentinian engineers were aware of new programmes being developed not only in Latin America, but all over the world. For instance, *Caminos* had a section called ‘Foreign Emphasis’ featuring very brief information about road programmes and general road-related news from varied countries such as Brazil, Ecuador, Turkey and Greece.[152] The Pan-American Highway Congresses were also crucial opportunities to get to know in detail what other countries in the continent were doing. Nevertheless, most of the references quoted in technical publications were either Argentinian or American.[153] Two Latin American countries seem to stand out though. Brazil and especially Mexico were important examples for the financing and development of networks of low-trafficked rural roads. As the next chapter will show for the case of Colombia, in Argentina Mexico’s financing scheme for this kind of project was considered pioneering and it was praised for connecting previously isolated parts of the territory.[154] The Brazilian example was also admired for the way in which technical knowledge was distributed, as in order to receive federal funding, the states were obliged to provide technical assistance to municipal authorities.[155] The extent to which these examples influenced Argentinian road engineers and administration remains to be studied, however.

It seems that by hosting international events and by comparing the country to the developed world, Argentinian road engineers were attempting to position themselves as relevant players in the field at a global level, and as leaders in Latin America. Argentinian engineers often compared the country’s transport system to that of European and North American countries – and not only with the ones in other South American countries. For instance, in 1970, to

[150] Juan F. García Balado, ‘Criterios Actuales y Tendencias en los Proyectos y Construcciones de Hormigón y Suelo-Cemento’, in *Carreteras*, n. 11 (Jul.-Sept. 1957), 49-53.
[151] Anon., ‘Vialidad Nacional Invertirá $ 443.000.000 en 1954’, in *Noticias Camineras*, n. 1 (May 1954), 7.
[152] For example, the January 1956 issue announced the launch of a new programme of road construction in Brazil, the completion of a new bridge in the frontier between Greece and Turkey and the creation of a new tax on naphtha in Ecuador to build roads connecting with other countries. Anon., ‘Enfoques Extranjeros’, in *Caminos*, 155 (Jan. 1956), 31.
[153] See e.g. Ezequiel Ogueta, ‘Predicciones de Tránsito Para Obras Viales Financiadas por el Sistema de Peaje’, in Dirección de Vialidad, Ministerio de Obras Públicas, Provincia de Buenos Aires, *Publicación N. 80* (Aug. 1968); DNV, *Memoria 1952-1953*, 53.
[154] Petriz, ‘Necesidades del País’, 16-17.
[155] Petriz, ‘Necesidades del País’, 17.

evaluate the evolution and significance of maintenance investment in Argentina, the DNV saw fit to compare its maintenance expenditure to that of the US (Figure 4.7).[156] Several comparisons of the sort can be found in the same report.[157] The main reference was the US, but some European countries (mainly France and Germany) were also often used as comparisons, as well as Mexico and Brazil.[158] To reinforce their position as relevant figures in road engineering, the DNV hosted various events, inviting representatives from prestigious organisations in the US, Europe and some Latin American countries. For example, in 1960, a conference about concrete construction was held in Buenos Aires, featuring papers by experts from the Highway Research Board, the École des Ponts et Chaussées, the Centro Italiano de Studi e Riserchi, the US Department of Public Works, and the Universidad Católica de Chile, amongst others.[159] In 1964, the Vth Argentinian Congress of Roads and Transit also assembled delegates from US, France, Sweden, Great Britain and a few Latin American countries.[160] In 1959 and 1966 Argentina also held two of the meetings of the technical commission of road terminology from the Pan-American Highway Congress, receiving delegates from Brazil, Cuba, Haiti, Peru, Venezuela, Uruguay and the US.[161] It is difficult to measure the success of the Argentinian engineers' attempts of positioning themselves at a global level. My research suggests that their initiatives had limited success outside Latin America, and that the role they played within the region was similar to that of Mexico and Brazil (see Chapter 5).

Figure 4.7 Graphs showing the evolution of maintenance expenditure in Argentina (1935-1970) and the US (1956-1968)

[156] DNV, *Panorama Vial*, 43.
[157] See e.g. the comparison of the rate of traffic growth and the related increases in maintenance costs (5.7 per cent per year for the US and 11 per cent per year for Argentina, which meant that maintenance costs in Argentina were duplicated every ten years, and not every twelve as it would be the case in the US). DNV, *Panorama Vial*, 41.
[158] See e.g. graph with the evolution of land freight transport by road and by train from 1945 to 1969 in Argentina, Brazil, Mexico, Germany, the US and France. Australia, Canada and South Africa were sometimes also considered comparable to Argentina. DNV, *Panorama Vial*, 2, 52.
[159] Anon., 'Técnicos Argentinos y Extranjeros en una Conferencia Sobre Hormigón', in *Caminos*, 214 (Dec. 1960).
[160] DNV, *Memoria 1963-1966*, 23.
[161] DNV, *Memoria 1959-1962*, 21; DNV, *Memoria 1963-1966*, 25.

[Picture removed from ethesis version on copyright grounds]

Note: The unit for the main graph is millions of pesos of 1960. For the US graph, the index is 1960 = 100.

Source: DNV, *Panorama Vial*, Fig. 21, 43.

The growth of construction firms and the increased use of materials laboratories and heavy machinery

After a period of decline in the 1940s related to imports barriers and the Second World War (see above), the Argentinian construction industry slowly recovered in the 1950s and especially in the 1960s, gaining the recognition of the World Bank as well developed by 1971. In 1960, although about 450 firms were registered to work for road projects with the DNV, a foreign study on the Argentinian transport sector commissioned that year found that the capacity of construction firms was very limited.[162] Construction works did not always respect the established specifications, a fact that another study attributed to the incompetence of the contractors and negligence of the DNV inspectors.[163] In addition, projects were frequently finished with delays, although this was also related to late payments and delivery of technical

[162] According to the consultants, although about 100 of the firms pretended to have a capacity of more than 30 million pesos a year, this was not accurate. A major factor was the poor condition of the plant. However, many firms did not provide the information requested, in particular surveys of their plant. The majority of firms had contracts for works for less than 50 million pesos per year. Only 14 firms had a capacity higher than that, of which only 3 had a capacity of 200 million pesos per year. Of the 191 projects in execution in 1960 (due to be finished in 2 to 4 years), the majority cost less than 20 million, and only 35 cost more than 30 million pesos. Coverdale & Colpitts et. al., *Estudio de los Transportes Argentinos*, 161, 166.

[163] TPG, *A Long Range Transportation Plan*, Appendix 2 Highways, 56.

instructions from the DNV (delays of four months or more).[164] Nonetheless, by the early 1970s, over twenty large construction firms were able to handle contracts of up to 15 million USD a year – although a few were subsidiaries of large international firms.[165] In the 1971 road project with the World Bank, local firms were able to win all the contracts bidding against international firms (partly because of low prices related to a lull in the pace of construction).[166] It is also telling that for that same project the vast majority of consulting firms engaged in detailed engineering were Argentinian.[167]

Furthermore, by 1961, almost twenty years after being founded, the LEMIT was receiving funds from private firms as well as from the Buenos Aires province, had a staff of 275 people (amongst which there were 110 technicians), an area of 5,000 square metres exclusively for laboratories and workshops, and an additional terrain with experimental plant and laboratories of about 3,500 square metres.[168] In this period, the LEMIT published 78 original research publications and analysed over 200,000 samples.[169] The laboratory was also a repository of both national and foreign knowledge, as its library contained over 8,000 items and some members of staff had attended specialisation programmes in the US, Brazil, France, Great Britain, Spain, Switzerland and Sweden.[170] Throughout the 1950s and 1960s, materials laboratories grew in number and capacity across the country and, in 1969, based on the experienced acquired, a programme to build several new mobile laboratories was being drafted.[171]

Finally, in the 1950s, as the Peronist government had started introducing higher wages and benefits for the workers, machines were becoming increasingly attractive for engineers and other staff at the DNV as a way to keep costs to a minimum.[172] As previously mentioned, machines were already in use in the first half of the century but, by 1950, a great number of machines were thought to be in poor condition, and both construction firms and the DNV

[164] The World Bank noted that in the early 1960s the road works it financed took twice as much time as they were meant to take and with higher costs than estimated. The Bank associated the delays with the instability of the government and an 'improper' use of the consultants. TPG, *A Long Range Transportation Plan*, Appendix 2 Highways, 56; IBRD, 'Appraisal of a Highway Project Argentina, 1971', Annexe 1, 1.
[165] IBRD, 'Appraisal of a Highway Project Argentina, 1971', 10.
[166] IBRD, 'Appraisal of a Highway Project Argentina, 1971', 10.
[167] IBRD, 'Appraisal of a Highway Project Argentina, 1971', Table 11.
[168] Anon., 'LEMIT', 22.
[169] Anon., 'LEMIT', 22.
[170] Anon., 'LEMIT', 25.
[171] DNV, *Memoria 1968-1969*, 39, 47.
[172] No details were provided comparing the costs of mechanised and manual labour. It seems quoting the opinion of American road experts was enough to legitimise the superiority of machines. See e.g. translation of an article by a works inspector at the Maintenance Division of the Highway Department in Texas: Spencer Jr., 'Prácticas de Mantenimiento de Carreteras', 20. DNV, *Memoria 1950*, 43.

considered they needed more. In the early 1950s, the DNV was struggling to find construction firms with the necessary plant and thus capacity to let some of its contracts.[173] Many construction firms were using machines considered old, which slowed down works and made them more expensive, even by the late 1950s.[174] Maintenance work was also suffering from a lack of machinery, and the DNV often used animals instead of machines in the early 1950s.[175] In fact, earth roads needed constant maintenance with heavy machinery (for re-profiling and remodelling) and some tasks were neglected due to machine scarcity, even in the early 1960s.[176] For instance, from 1959 to 1962, limited maintenance was conducted on the less trafficked roads, reducing the attention paid to drainage, passes, traffic signs, amongst others.[177]

The shortage of machinery was also related to the difficulty of getting spare parts. Many machines stayed idle for long periods of time due to the unavailability of spares, worsening their condition.[178] For instance, in the late 1950s, the DNV had at its disposal about 2,500 machines, of which only 60 per cent were in good condition, 11 per cent needed to be discarded, and the rest were waiting for spares and repairs.[179] In fact, despite the imports of machines made possible by two loans from the World Bank and the Export-Import Bank in the late 1950s, spare parts remained a problem. The DNV bought with these loans more than 1,000 machines, amongst which featured 699 motor graders and 404 tractors of different kinds.[180] The machines were mostly from the US, but a small proportion came from Italy, Great Britain and Japan.[181] However, Argentina's protectionist measures in the post-war period made the importing of spare parts difficult. Many road engineers saw this policy as harming, since manufacturing some spare parts was expensive and time consuming.[182]

Nonetheless, it seems that this policy did result in the production of different types of road-building machines in Argentina, although more research is needed on this topic. By 1957,

[173] De Carli, 'Aspectos Generales del Problema Vial', 43; DNV, *Memoria 1950*, 42.
[174] 'Anon., 'La Importación de Maquinaria Vial', in *Caminos*, 178 (Dec. 1957); CEPAL, *Los Problemas del Transporte de la Argentina*, 287.
[175] This practice was common in the early 1950s but there was no mention of it after 1953. DNV, *Memoria 1951*, 113; DNV, *Memoria 1952-1953*, 158.
[176] DNV, *Memoria 1959-1962*, 33.
[177] DNV, *Memoria 1959-1962*, 33.
[178] Coverdale & Colpitts et. al., *Estudio de los Transportes Argentinos*, 160.
[179] 80 per cent of these machines were used for maintenance, 15 per cent in the construction works undertook by the DNV, and 5 per cent were lent to contractors. Coverdale & Colpitts et. al., *Estudio de los Transportes Argentinos*, 171.
[180] DNV, *Memoria 1959-1962*, 57.
[181] DNV, *Memoria 1959-1962*, 57.
[182] For instance, electrical hammers were no longer in use because of the impossibility of importing them and of manufacturing them. 'Anon., 'La Importación de Maquinaria Vial', in *Caminos*, 178 (Dec. 1957), 32.

there were eight factories making a significant contribution to the mechanisation of road works, especially in relation to small machines.[183] The DNV did not keep an inventory of machines according to their origin, however; and it also seems that a considerable portion of national production actually corresponded to manufacturing foreign brands according to their designs (Figure 4.8). Despite the good quality of the machines produced, the factories struggled due to the lack of continuity of the demand resulting from the absence of a sustained purchase plan from the DNV and from the lack of credit opportunities available to the construction firms.[184] Moreover, most tractors produced in these factories were destined for agricultural production, and not road works.[185]

Figure 4.8 Advertisement of Trillor, distributor of Sika products in Argentina, 1956

[Picture removed from ethesis version on copyright grounds]

Source: Trillor, ‘Equipos Vibradores y Compactadores para la Construcción y Pavimentos’, in *Caminos*, 161 (Jul. 1956), 34.

Despite these problems, the number of machines used in the country increased considerably during the period. For instance, as Table 4.1 shows, the number of tractors owned by the

[183] ‘Anon., ‘Lo Esperado: Tendremos Máquinas Viales’, in *Caminos*, 165 (Nov. 1956); Manuel J. Cintolo, Síntesis del Nacimiento y Desarrollo de la Industria Vial’, in *Carreteras*, n. 11 (Jul.-Sept. 1957), 55.
[184] Cintolo, ‘Síntesis del Nacimiento y Desarrollo de la Industria Vial’, 55.
[185] Cintolo, ‘Síntesis del Nacimiento y Desarrollo de la Industria Vial’, 55.

DNV almost multiplied by ten from 1943 to 1968-69, as did the number of motor-graders. Lorries were very numerous, which was connected to the need to transport large amounts of materials over long distances (see also Chapter 5). Similarly, the large number pick-ups and jeeps (and the large quantity of caravans), could be related to the long distances and to the need to transport workers to distant working sites.[186] Unlike the cases studied in Chapter 3 and 5, however, Argentina continued to use a large number of non-motorised graders until the late 1960s. The use of these machines was related to the early experience of motorisation in Argentina, as they were already widely employed for road construction in the 1930s, pulled by tractors.[187]

Table 4.1 Number of some of the most numerous machines owned by the Dirección Nacional de Vialidad and used for maintenance works (1943, 1958, 1968-69)

		Tractors	Motor Graders	Graders	Lorries	Pick-ups and Jeeps
Total DNV	1943	164	88	345	283	129
	1968-69	1054	771	662	992	611
Only used for maintenance	1958	300	451	n.d.	700	n.d.
	1968-69	510	730	n.d.	435 (*)	450

(*) This figure includes 320 dumper trucks and 115 'camiones regadores'.

Sources: DNV, *Memoria 1943*, 143; Dirección Nacional de Vialidad, *Memoria 1957-1958*, 64; DNV, *Memoria 1968-1969*, 151, 162-69.

The increasing use of machines required knowledge about how to coordinate, operate and repair them. Engineering journals were an important tool to keep road engineers up to date with the newest machines in the international market.[188] The DNV also played an important role in diffusing techniques of operation and repair. In the late 1960s, the Dirección Principal

[186] The DNV had about 800 caravans in 1968-69. DNV, *Memoria 1968-1969*, 162-169.
[187] Bustos, 'Caminos de Bajo Costo', 19-39.
[188] See e.g. Anon., 'Equipos para Obras Camineras', in *Caminos*, 283 (Sept. 1966), 39; 'Anon., 'Maquinaria y Equipos', in *Caminos*, 291 (May 1967), 42.

de Equipos at the DNV was in charge of sending inspectors across the country, distributing machine maintenance manuals to operators and mechanics.[189] This practice obtained good results according to the DNV, as the number of accidents diminished and the machines seemed to be having longer lives.[190] Supervision was also a major task for the DNV. Maintenance was directed by foremen responsible for sections of different size; in the early 1960s sections consisted of 400 to 500 km of roads, although when roads were paved or bore heavy traffic the length was reduced to 200 km.[191] Since the maintenance of the national network was managed by the DNV from Buenos Aires, the successful coordination of such a massive enterprise over such a vast territory is remarkable. Already in 1943, more than half of the national network was receiving constant maintenance, evidence of the significant experience the DNV had acquired before the war, and by 1961 the proportion of national roads that were regularly maintained had already reached over 94 per cent.[192]

Despite the rising number of machines, manual labour continued to be important throughout the period. In 1968-69, for example, although the DNV used more than 700 tractors for maintenance, it employed more than 10,000 labourers on this type of works every year.[193] Almost half of these workers were not permanent employees: they were 'transitory', probably hired for particularly demanding projects and times of the year.[194] Without including the costs of buying machinery, the DNV could sometimes spend more on personnel than on machine operation per year. That was the case of the maintenance division of the DNV in 1969, for example.[195] This was related to the fact that the staff needed for machine warehouses and workshops were not included in the category of machine operation, but in personnel (along with the staff needed for various tasks such as ferry operation and planting of trees along roads).[196]

[189] DNV, *Memoria 1968-1969*, 160.
[190] DNV, *Memoria 1968-1969*, 161.
[191] Accordingly, when foremen dealt with roads with light traffic, the length of the network they were possible for could considerably increase. TPG, *A Long Range Transportation Plan*, Appendix 2 Highways, 57.
[192] DNV *Memorias* 1943 through to 1966.
[193] DNV, *Memoria 1968-1969*, 128.
[194] In general, the upkeep of paved roads required a higher proportion of money for personnel than the upkeep of unpaved roads. In 1969, for example, the investment to maintain a paved road corresponded to 37 per cent for personnel expenses and 26 per cent for plant. In contrast, to maintain an earth road with no surface treatment, the investment needed corresponded to 32 per cent for workers and 45 per cent for machines. DNV, *Memoria 1968-1969*, 149, 153.
[195] In 1969, about 58.7 million pesos were spent on personnel, while 57.3 million pesos were spent on plant (the rest, 20.8 million, corresponded to goods and services). DNV, *Memoria 1968-1969*, 149.
[196] Personnel expenditure also included routine maintenance, repairs and improvements. DNV, *Memoria 1968-1969*, 149.

Conclusion

In the early twentieth century, Argentina's transport system reflected the country's wealth. Not only was the railway system large, the rapidly growing road network was built with the latest methods and machinery at the time, i.e. following the American model. This included the construction of low-cost roads and the use of earth-moving machinery and materials laboratory tests. However, from 1950 to 1970, road freight surpassed railway freight – a shift related to the decline of the railway system. The growing traffic of lorries caused serious strain on the road network, which had not been built to bear such heavy loads. At the same time, the funds available to the DNV were limited due to inflation but also in great part due to the state's incapacity to adapt the tax legislation to the changing financial situation of the country, as well as to its prioritisation of YPF.

Nonetheless, the DNV managed to respond to the rising demands with a policy that combined routine maintenance, relatively small progressive improvements (especially from 1950 to 1960), and a shift from building mostly unimproved earth roads to building almost exclusively all-weather roads (from 1950 onwards, but especially in the 1960s). The pace of construction did not attain the levels of the 1930s and early 1940s again after 1944 – when lorry traffic was rising to unprecedented levels. Although the construction of all-weather roads contributed significantly, the massive increase of lorry transport from 1950 to 1970 would not have been possible without the major maintenance, improvements, and paving efforts of the DNV. In this process, the experience that the DNV and the private sector had acquired in the two decades before the Second World War proved invaluable. The number of materials laboratories and road-building machines rose. Construction firms gained capacity and the length of the national road network that was constantly maintained by the DNV reached 94 per cent by 1961. Although Argentinian road engineers followed the work of their counterparts in other countries, and in particular Mexico and Brazil, the US continued to be their main reference throughout the period, not only in technical, but also in administrative terms.

Chapter 5 The unintended role of maintenance in Colombian road development, 1950-1970

In the 1950s and 1960s Colombia experienced a major transformation of its transport system. From carrying about the same volume of freight (in ton-km) as railways in 1950, by 1970 motor vehicles were carrying more than 70 per cent of freight.[1] However, there was relatively little road building during the period.[2] This chapter examines how Colombia's road infrastructure allowed for the radical increase in road transport over the 1950s and 1960s. It argues that road maintenance and improvements enabled the growth of increasingly heavy traffic over mostly unpaved roads. Further, this chapter argues that this phenomenon was not the result of a clear planned policy, but rather of the state's inability to make new and old railway transport competitive and of its failure to offer adequate support and planning for the construction of a road network that could satisfactorily face the challenging traffic and environmental conditions. Attempting to render the existing national road infrastructure fit to respond to the rising transport demands, the Ministry of Public Works (Ministerio de Obras Públicas, MOP) accelerated the mechanisation of maintenance, and promoted the adaptation of foreign knowledge, practices and techniques, from not only the US and Europe, but also from other Latin American countries (as its counterpart did in Argentina, Chapter 4). Nevertheless, the MOP's administrative problems limited the success of its modernising efforts. Therefore, despite allowing the growth of traffic, road conditions continued to be poor and the flow of traffic highly weather dependent.

The economic historian Álvaro Pachón shows in his overview of the Colombian transport infrastructure in the second half of the twentieth century that roads became the most prominent transport method in the period despite being mostly unpaved. For him, the rise in road transport facilitated the integration of the national market and promoted economic growth, especially during the 1950s. Pachón argues that this was a result of economic policies, and not of a transformation of the road infrastructure, since by the middle of the twentieth century roads were already connecting the largest urban centres to each other, as

[1] Álvaro Pachón, 'La Infraestructura de Transporte en la Segunda Mitad del Siglo Veinte', in Álvaro Pachón and Maria Teresa Ramírez, *La Infraestructura de Transporte En Colombia Durante El Siglo XX: Una Descripción Desde El Punto de Vista Económico* (Bogotá, 2006), 277-486.
[2] Even with the problems caused by the Great Depression and the Second World War, more kilometres of road were built from 1930 to 1950 than from 1950 to 1970 (about 10,200 km and 7,700 km respectively). Pachón and Ramírez, *La Infraestructura de Transporte En Colombia*, 55, Anexo II.37.

well as to the main production areas.[3] However, he does not explain how a network of mostly unpaved roads in poor condition allowed for such a radical increase in road transport. I will show that maintenance is key to understanding this phenomenon.

Historians Marta J. Villaveces and Ramón E. Hernández argue that the Colombian Government prioritised road maintenance over new construction from 1945 to 1990, and they associate this with the neglect of road development in favour of electric energy.[4] However, they do not present any evidence of the proportion of funds invested in maintenance as compared to construction, they do not study what maintenance meant or entailed, and they make only marginal references to the investment in other transport methods. In addition, they argue that prioritising road maintenance was the result of a planned policy. I will challenge their arguments by showing first that the state spent more on construction than on maintenance and, second, that despite the investment priorities, maintenance did acquire an essential role, not as part of a governmental plan, but as the result of the state's limited success building roads and promoting railway traffic.

The Colombian transport system makes for a particularly interesting case given its unusual combination of road, rail, animal, and river transport, as well as due to the location of its capital Bogotá at 2,600 m above sea level, about 500 km away from the Pacific coast, and over 900 km away from the Caribbean coast. In 1950 Colombia's transport system consisted of 3,000 km of railways (built mostly between the 1900s and 1920s), 12,200 km of roads (built mostly in the 1930s and 1940s), navigation from the interior towards the Caribbean over the Magdalena River, and a network of mule tracks. Pack mules were the major land transport method since the sixteenth century, and they not only survived but also in many instances thrived with the arrival of the railways in the late nineteenth century.[5] Mules continued to play an important economic role, especially in the mountainous coffee regions, at least until the 1930s, when roads started to replace them.[6] Although cases in which animal and rail transport coexisted an complemented each other are not uncommon, the economic centrality of pack animals in the twentieth century is a more unusual phenomenon, comparable perhaps to other Andean countries and to the camel caravans of the Sahara. Furthermore, the Magdalena River, which had played a crucial role since colonial times,

[3] Pachón, 'La Infraestructura de Transporte' and María Teresa Ramírez, 'Desarrollo de la Infraestructura de Transporte en Colombia, 1900-1950', in Pachón and Ramírez, *La Infraestructura de Transporte En Colombia*, 54-55.
[4] Marta Juanita Villaveces Niño and Ramón Eduardo Hernández Ortega, 'Carreteras y Red Eléctrica en Colombia, 1945-1990', in *Economía & Región*, 11 (June 2017).
[5] Germán Ferro Medina, *A Lomo de Mula* (Bogotá, 1994).
[6] Ferro Medina, *A Lomo de Mula*.

remained a major transport artery throughout the twentieth century, despite the problems it presented during periods of both heavy and scarce rains. The Magdalena River was not replaced by the Ferrocarril del Atlántico, the railway that ran parallel to it (built from 1953 to 1961), for the latter attracted little business. Unable to coordinate the different transport methods at its disposal, the Colombian state failed to take full advantage of this multimodal system, putting increasing pressure on the road network.

The evolution of road and rail transport in Colombia tells a similar story to the one in Argentina over this period, although at a different scale given Colombia's considerably lower income. In the 1920s, while Argentina's GDP was the highest in Latin America, Colombia's was one of the lowest.[7] Although Colombia reached rates of GDP growth of 4.6 per cent and 5.2 per cent in 1950-1960 and 1960-1970 respectively, by 1968 Colombia's GDP was approximatively three times lower than Argentina's (which was by then lower than that of Mexico and Brazil).[8] The scale of road construction was also different: whereas Argentina built about 35,000 km of national roads from 1934 to 1969, Colombia only built 17,915 km of national roads from 1931 to 1970.[9] The density of the Argentinian total road network was considerably higher than that of Colombia throughout the period. While Argentina had about 80 km of road per 10,000 inhabitants in 1954, Colombia had less than 20 km, and by 1967 these densities had increased to 86.3 km and 23.5 km respectively.[10] By 1970, Argentina had 0,07 km of road per square kilometre, while Colombia had 0,04 km of road per square kilometre.[11] Traffic was also much heavier in Argentina; for example, in 1968 Argentinian national roads carried 26,671 million ton-km of freight, while Colombian national roads carried about 10,285 million ton-km in 1970.[12] In addition, Argentina's railway network was

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[7] Victor Bulmer-Thomas, *The Economic History of Latin America since Independence, 3rd ed.* (New York, 2014), 161, Appendix 4, 528.

[8] The Economic Commission for Latin America and the Caribbean estimated that in 1968 Colombia's GDP at factor cost was 6,959 million USD (at 1960 prices), while Argentina's was 20,103 million USD (at 1960 prices). Comisión Económica Para América Latina (CEPAL), *Boletín Estadístico de América Latina*, Vol. VI, No. 2 (New York, 1969), 22.

[9] Dirección Nacional de Vialidad, *Memoria 1963-1966* (Buenos Aires, s.d.), 13; Biblioteca Nacional Mariano Moreno (Argentina). Departamento de Archivos. Fondo Centro de Estudios Nacionales, Subfondo Arturo Frondizi (hereinafter AR-BNMM-ARCH-CEN), 03.4.4.4 Caja UC 108. Naciones Unidas Consejo Económico y Social, Comisión Económica Para América Latina, *Los Problemas del Transporte de la Argentina y la Orientación de sus Soluciones* (Santiago de Chile, 1958), 79; Dirección Nacional de Vialidad, *Memoria 1968-1969* (Buenos Aires, s.d.), 10; Pachón and Ramírez, *La Infraestructura de Transporte En Colombia*, 55, Anexo II.37.

[10] CEPAL, *Boletín Estadístico de América Latina*, 135; Ramírez, 'Desarrollo de la Infraestructura de Transporte en Colombia, 1900-1950', 57.

[11] These densities per 10,000 inhabitants and square kilometre include all types of roads, and not just national networks. See Annexe A. In 1967, Argentina's territory was about 2,770,000 sq. km while Colombia's was about 1,138,000 sq. km. CEPAL, *Boletín Estadístico de América Latina*, 27.

[12] See Graph 4.1 and Pachón and Ramírez, *La Infraestructura de Transporte En Colombia*, Anexo II.9.

over ten times larger than Colombia's in 1950 (42,800 km and 3,000 km respectively).[13] Another significant difference is that, unlike Argentina (and most Latin American nations), Colombia engaged in a large railway construction project during this period. The Ferrocarril del Atlántico was about 670 km-long and connected the capital with the northern railway terminus of Fundación, therefore linking Bogotá to the Caribbean coast.[14] However, this major investment did not meet with success and did not stop the decline of the railways. Therefore, despite these various differences, both countries experienced a shift from railways to roads as main transporters of freight from 1950 to 1970. Both nations managed to respond to these demands mostly by maintaining and improving the road network, experiencing a slower pace of construction in this period than in the two previous decades.

As we have seen in Chapters 3 and 4, the mechanisation of maintenance was a significant phenomenon of the post-war period, especially due to the large proportion of unpaved roads. Similar fleets of machines were used in Colombia. For instance, motor-graders were considered essential for maintenance works, especially on unpaved roads and, in the 1950s, one motor-grader was used to maintain more or less 200 km of road, while efforts were being made to increase the number of these machines. In addition, similarly to Argentina, dumper trucks acquired a particularly important role due to the need of moving large quantities of materials. Although in all the cases studied local conditions and the scarcity of funds made necessary the adaptation of certain machines to perform maintenance tasks, such as tractors and lorries (and, in this case, dumper trucks), in Colombia the need for specialised road machinery was more pressing because of the structural deficiencies of the network. In fact, in Colombia there seems to have been considerably less control over road construction and maintenance than in Ivory Coast, as the MOP offered little technical guidance to the emergent Colombian construction firms, and foremen with little experience were in charge of supervising and coordinating maintenance. This meant that most roads had poor technical standards and road maintenance often involved reconstruction – an arduous task that was especially difficult without experienced staff and modern machinery. In fact, unlike Argentina, Colombia did not experience an early modernisation of road construction and maintenance, and this generated an additional challenge for the MOP, which struggled to manage and coordinate efficiently the new road maintenance mechanised regime. Finally, although both countries suffered from political instability during the period, Colombia

[13] See above and Chapter 4.
[14] At the time the capital was already connected to the Pacific coast by rail. Carlos Sanclemente, 'Ferrocarril del Atlántico', in *Credencial Historia*, 116 (1999).

experienced a violent internal conflict known as 'La Violencia' from 1948 to 1958, as well as the emergence of guerrillas in the 1960s.[15]

This chapter argues that maintenance and improvement efforts were the factors that allowed the national road infrastructure to respond to the rising transport demands in this period. The first section shows that the important role that improving and maintaining acquired was actually unintended. Despite growing investment in both railway and road development (from the National Government and the World Bank), the state failed to make railways a competitive transport system and obtained little results from its road construction programmes. While railways were losing traffic to heavy vehicles, the lack of adequate planning and technical support from the MOP produced few and deficient new roads. In this context, maintenance and improvements were the factors keeping roads passable and allowing for the massive increase in road transport. The second section of the chapter examines what these maintenance processes entailed. After examining the challenges the MOP encountered, I argue that the poor technical specifications of the roads made maintenance particularly difficult. These deficiencies demanded structural modifications of the roads, making the acquisition of more heavy machinery desirable, if not necessary given the urgent demands. The growing number of mostly American machines required new knowledge to work with them – from operators, engineers and administrators. Both national and foreign knowledge, practices and techniques were mobilised and, even though the US had a predominant role in terms of the production and circulation of road engineering knowledge, a Latin American engineering network was also influential for Colombian roads. This section ends presenting the limits of the modernisation of maintenance and improvement processes. The MOP's administrative issues dispersed resources and hindered its efforts, which is why roads did not reach optimal conditions.

The main sources used in this chapter were the archives of the MOP at the Archivo General de la Nación (AGN), and the Memoirs of the MOP that can be found in the library of this archive.[16] The main national engineering journal, *Anales de Ingeniería de Colombia*, also provided important technical information and as well as valuable insights into the technical debates in which Colombian engineers participated. The Biblioteca Nacional and the Ramón de Zubiría library at the Universidad de los Andes also offered transport studies and road engineering publications made or commissioned by the MOP. Finally, Maria Teresa Ramírez

[15] Although further research is needed to determine how these factors affected transport infrastructure, the armed conflict certainly had an impact on the funds available and the socio-political context.
[16] Although the MOP changed its name to Ministerio de Obras Públicas y Transporte in 1960, we will retain the acronym MOP throughout this chapter.

and Álvaro Pachón's book on Colombia's transport development over the twentieth century was particularly useful, as it contains considerable data on transport development.[17]

The unintended role of maintenance and improvements

The failure of the railways and the rise of road transport

In 1950, despite the impulse that road construction received in the previous two decades, the national road network was in poor condition. Road construction over the 1930s and 1940s had not followed an integrated plan but rather the political interests of individual members of Congress with little consideration for technical studies, resulting in an unfinished and fragmented network.[18] To make matters worse, the rainy seasons of 1945 and 1950 destroyed a significant part of the road infrastructure, and by 1950 less than one per cent of the national road network was paved.[19] Despite this, as previously mentioned, by the middle of the twentieth century the road network linked the main cities and productive areas.[20] Annexe M shows how concentrated the road and rail networks were, following a north to southwest axe, which corresponds more or less with the Andes mountain chain, connecting Bogotá and other large cities in the interior to the Pacific and Caribbean coasts.

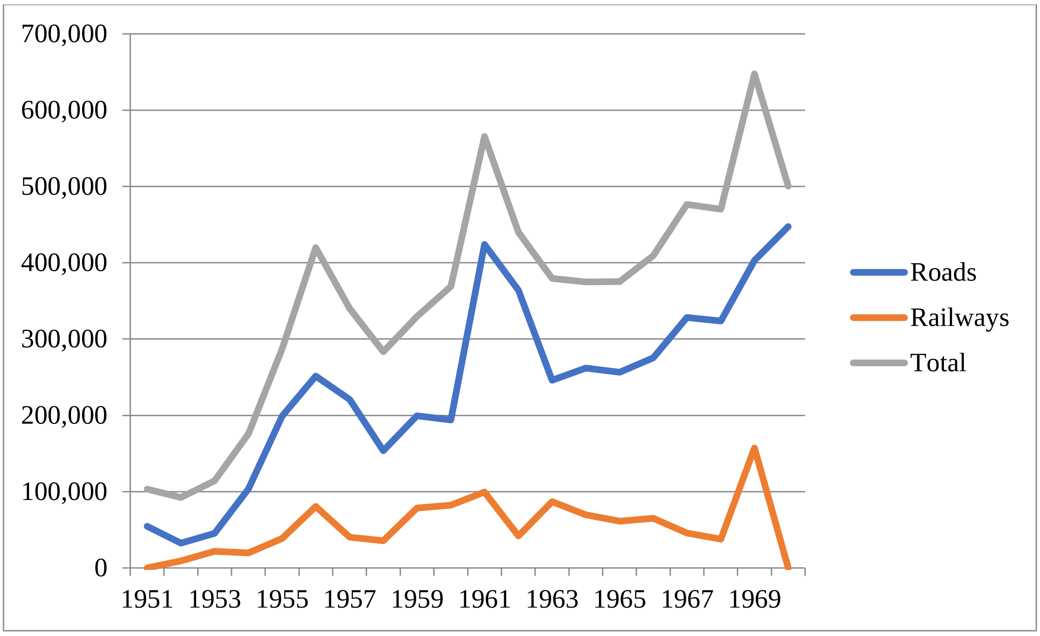
In the second half of the twentieth century, investment in both the railway and road infrastructures grew. Public investment in roads increased significantly faster than in railways as Graph 5.1 illustrates, and multiplied by more than eight times during this period.[21]

[17] In particular, it contained a CD-ROM with several tables, graphs and maps with data collected by them from various sources including the Ministry of Public Works, the National Administrative Statistics Department (DANE), and the World Bank, among others.
[18] Ramírez, 'Desarrollo de la Infraestructura de Transporte en Colombia, 1900-1950', 63.
[19] Annexe O.
[20] Ramírez, 'Desarrollo de la Infraestructura de Transporte en Colombia, 1900-1950', 54-55.
[21] The government used different means to collect money for road development. From 1954, construction contracts started being assigned to private firms through concessions financed with income from tolls and bridge-tolls. Tolls were managed by Juntas that supervised the collection and the investments. In December 1966, an ad-valorem tax on fuel consumption was established at the rate of 114 per cent over the refinery price for petrol, and 55.5 per cent for the case of Diesel (previously the tax was fixed at 15 cents per gallon of petrol). The same year, the National Road Fund was established, collecting money from the fuel taxes, tolls and other additional funds for particular projects from the national government. Therefore, taxpayers were in the late 1960s paying for about 50 per cent of the government's national road expenditures. MOP, *Memoria de Obras Públicas 1960* (Bogotá, 1960), 147; Herman Felstehausen, *Conceptos de Planeamiento Para Mejorar Carreteras y Caminos Colombianos* (Bogotá, 1969), 13; Asociación Colombiana de Ingenieros Contratistas (ACIC), *Quinto Congreso de Ingeniería de Obras Públicas, Anales, Tomo I* (Bogotá, 1965), 98; IBRD, IDA, 'Appraisal of the Sixth Highway Construction Project, Colombia' (Washington D.C., 1970), 6. Another fund was created in 1960 to finance the 'Caminos Vecinales', rural roads of local importance that were mostly unpaved and had low traffic, see Anon. 'Fondo Vial', in *Anales de Ingeniería de Colombia*, 76 (1st Trimester 1968), 21.

However, although railway investment through the newly nationalised Ferrocarriles Nacionales de Colombia (FNC, 1954) grew at a much slower rate, it was nonetheless significant. The construction of the Ferrocarril del Atlántico (from 1953 to 1961) was the single most expensive transport project of the period.[22] Its construction was suggested by the first World Bank Mission in Colombia as a way to diminish transfers between rail and other methods and allow for a more efficient use of equipment and maintenance facilities.[23] At this prospect the National Government invested over 470 million pesos, or about 70 per cent of the total cost of the project. [24] Money also came from the World Bank. From 1951 to 1970, during the same period, the Bank lent 93.7 million USD for railway construction, rehabilitation and improvement projects (compared with nine road projects covered with World Bank loans of 135.5 million USD).[25] Apart from financing the Ferrocarril del Atlántico, the Bank also lent money to build new railway repair shops and purchase new equipment and spare parts.[26] Therefore, although investment from both the National Government and the World Bank prioritised roads over railways, railways were still an important item in their economic development agendas.

Graph 5.1 Evolution of road and rail investments from the Colombian National Government, 1951-1970 (millions of pesos of 1997)

[22] Pachón, 'La Infraestructura de Transporte', 281-283.
[23] World Bank (WB), *The Basis of a Development Program for Colombia : Summary (English),* (Washington, D.C., 1950), 29.
[24] Pachón, 'La Infraestructura de Transporte', 281-283.
[25] World Bank Projects and Operations http://projects.worldbank.org/ (26/04/2018)
[26] See e.g. the first railway loan from the World Bank to the Colombian Government in 1952 for a total of 25 million USD. http://projects.worldbank.org/P006687/railway-construction-rehabilitation-project?lang=en (21/06/2018)



Source: Based on data from Pachón and Ramírez, *La Infraestructura de Transporte en Colombia*, Anexo II.7B.

However, investment in railways did not stop the decline of the FNC. The Ferrocarril del Atlántico was a disappointment: construction took longer than expected due to the lack of adequate preliminary studies and to execution problems that included losses related to the actions of subversive groups.[27] Moreover, as historian Álvaro Pachón has stated, the railway never attracted the freight it was expected to carry as the Magdalena River maintained its traffic by managing to accommodate the increased demand and by remaining cheaper than rail transport throughout the period.[28] In fact, the focus on the Ferrocarril del Atlántico might have had negative consequences for the railway system as it resulted in a reduced maintenance budget for the rest of the network. Efforts to modernise the railway system seem to have been too little too late. For instance, the purchase of Diesel-electric locomotives in 1967 seems to have had counterproductive results, as the sleepers and rails were in bad conditions and were too light for the new heavy locomotives.[29] The cost of rail transport increased steadily during the period, making railways unable to compete with lorries, which were gradually improving their service. In fact, in 1949 the cost of transporting one ton-km was about 1.2 pesos by road and 0.07 pesos by rail and, by 1972, the costs were 0.29 and 0.59

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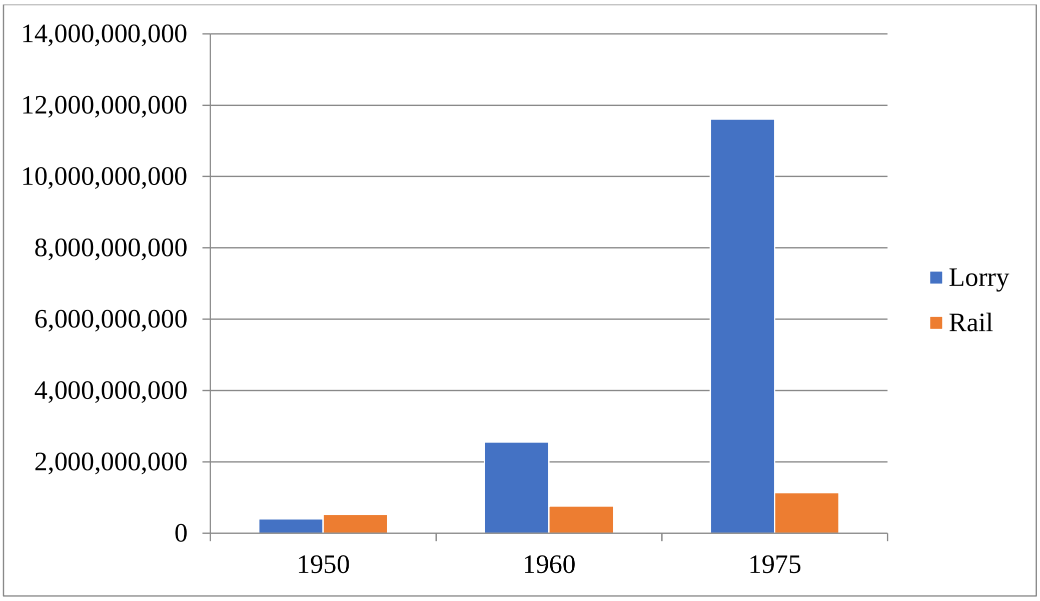
[27] WB, *The Basis of a Development Program for Colombia*, 29; Pachón, 'La Infraestructura de Transporte', 281.
[28] Pachón, 'La Infraestructura de Transporte', 282, Cuadro II.16.
[29] Gustavo Arias de Greiff, *La Segunda Mula de Hierro* (Bogotá, 2006), 95.

respectively.[30] This caused a continuous decrease in railway traffic, only exacerbating the deficit of FNC, which historians have attributed to institutional problems, bad tariffs policy design, and the lack of homogeneity of the system, amongst other factors.[31]

It is not surprising, therefore, that railways were increasingly losing traffic to lorries. The lack of coordination between rail and road transport had started in the first half of the century, but the second half saw the aggravation of this phenomenon.[32] As we can see in Graph 5.2, even though both methods carried similar freight volumes (in ton-km) at the start of the period, and even though railway freight did increase in these two decades, freight transported by lorry grew significantly faster. The comparison of the land transport networks over time also shows how the majority of the new roads built in the 1950s and 1960s ran parallel to railways, such as the road connecting Bogotá to the Magdalena River and the one linking Medellín and Cali – and thus to the Pacific port of Buenaventura (see Annexes M and N). Indeed, while the FNC struggled with rising deficit and a decreasing share of goods traffic, road transport was becoming faster and freight suffered less damages and losses on lorries than on rails, making road transport cheaper, 'even in the cases in which transport by rail was substantially lower'.[33] Therefore, the state's failure to make the railways competitive and coordinate between rail and road traffic contributed to the predominance roads acquired during the period. In an easier and cheaper way than the railways, roads could still allow traffic continuity and growth even if maintenance conditions were not optimal which, in the context of a poorly planned and executed transport policy, put them at a clear advantage.

Graph 5.2 Transport of freight by rail and lorry in Colombia in 1950, 1960 and 1975 (ton-km)

[30] In pesos corrientes (nominal value). Figure does not take into account regional differences. Pachón and Ramírez, *La Infraestructura de Transporte en Colombia*, Cuadro II.16.
[31] See e.g. Ramírez, 'Desarrollo de la Infraestructura de Transporte en Colombia, 1900-1950', 54-55.
[32] Donald S. Barnhart, 'Colombian Transportation Problems and Policies, 1923-1948' (Univ. of Chicago D.Phil. thesis, 1953), 190-193.
[33] MOP, Parsons, Brinckerhoff, Quade & Douglas, *Estudio del Transporte Nacional: Plan de Mejoramiento para los Transportes Nacionales* (Bogotá, 1962), I-15.



Source: Based on data from Pachón and Ramírez, *La Infraestructura de Transporte en Colombia*, Cuadro II.20.

The limits of road construction and the unintended role of maintenance

The majority of the money the government spent on roads was directed towards road construction. Although funds for maintenance represented a significant proportion, they did not correspond to more than 50 per cent of the annual national investment on roads throughout the period. Figure 5.1 illustrates how in 1950 almost 50 per cent of the budget for roads was spent on maintenance, and in 1958 about a third of the budget was used for this purpose.[34] In 1969, maintenance funds had once again risen to correspond to 40 per cent of annual expenditure on roads.[35] Although these figures are not precise (and some improvements actually required significant reconstruction works, while construction might have also included expensive permanent structures such as bridges and tunnels), they do suggest that maintenance was not the highest investment priority of the government. In particular, maintenance expenditure never exceeded construction expenditure, as it did in Argentina in the early 1950s (see Chapter 4).

Figure 5.1 Graph comparing road construction and maintenance expenditure in Colombia, 1949-1958 (pesos)

[34] MOP, *Memoria de Obras Públicas 1958* (Bogotá, 1958), 33
[35] Herman Felstehausen, 'Planning Problems in Improving Colombian Roads and Highways', in *Ekistics* 31 (June 1971), 440.

[Picture removed from ethesis version on copyright grounds]

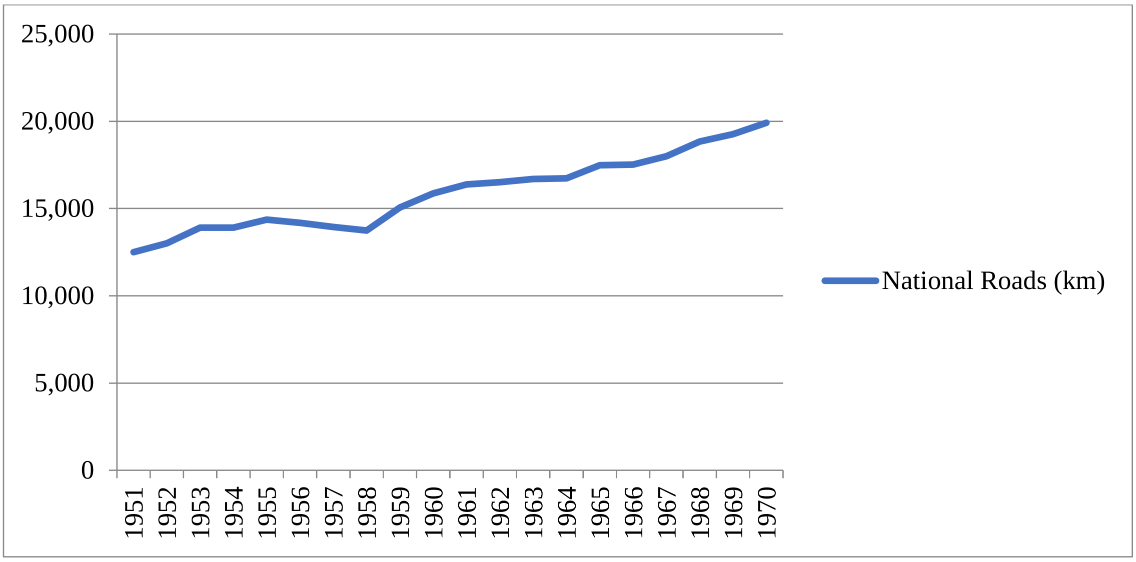
Note: in dark grey, maintenance.

Source: MOP, *Memoria de Obras Públicas 1958*, 33.

Nevertheless, the rise in construction funds was not reflected in the extension of the road network. This becomes evident if we compare public investment in roads with the growth of the road length (see Graphs 5.3 and 5.4). While funds for road development multiplied by eight times, the length of the network did not even double going from 12,200 km to 19,915 km (see Annexe O). Although it is not clear what operations the money for road construction was meant to fund (it is possible that the creation of materials laboratories was included, for example), it seems that the extension of the road length was indeed a key objective, as frequent complaints about the delays of construction works from the MOP and the World Bank suggest. In fact, some of the World Bank loans in the 1960s included road projects that were supposed to be finished with the help of previous loans. For instance, in 1961, the Roads Project financed by the Bank included the continuation of the construction of 721 km of roads started under earlier projects.[36]

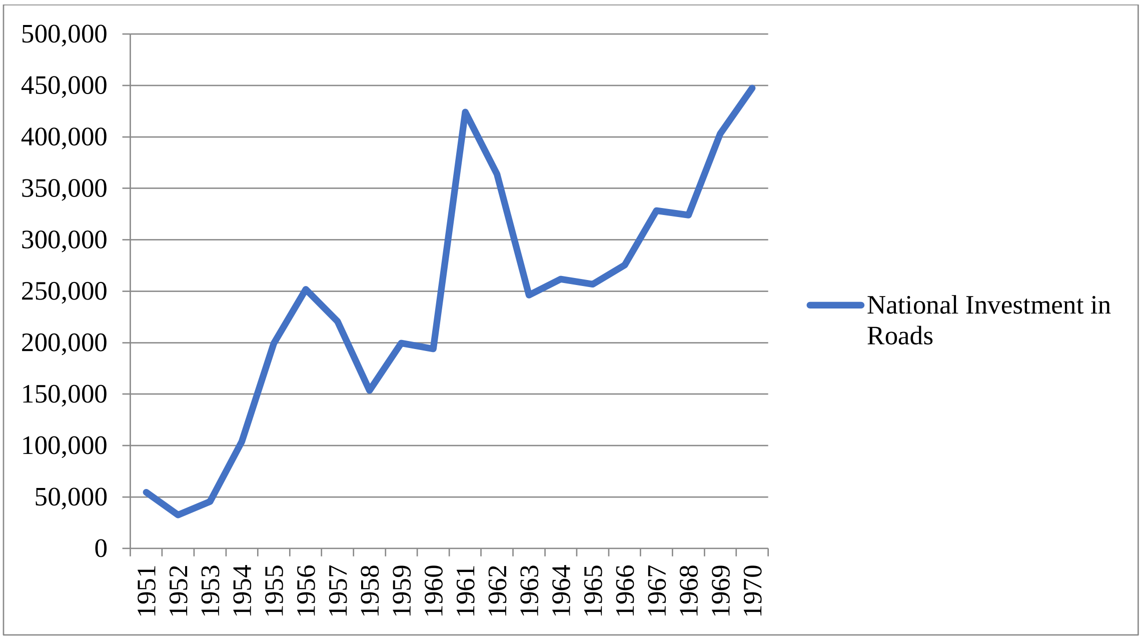
[36] IBRD, IDA, 'Appraisal of a Fourth Highway Project, Colombia' (Washington D.C., 1961), i.

Graph 5.3 Length of the Colombian national road network, 1951-1970 (km)



Source: Based on data from Pachón and Ramírez, *La Infraestructura de Transporte en Colombia*, Anexo II.37.

Graph 5.4 National investment in road development in Colombia, 1951-1970 (in million pesos of 1997)



Source: Based on data from Pachón and Ramírez, *La Infraestructura de Transporte en Colombia*, Anexo II.7B.

In fact, the lack of adequate planning and the consequent continuous modifications of the projects generated a great waste of resources and made progress on construction slow. First, different institutions had the power to intervene in road development decisions, which resulted in a lack of coherence. Although the MOP created two road development plans for the national road network during the period (the Plan Vial 1 and 2), the National Congress could also approve the construction of simultaneous road projects.[37] The Congress did not have to coordinate its actions with the MOP and was free to evaluate the benefits of road projects according to its own criteria, which were often more political than economic, social, or technical.[38] Without a general road development plan, efforts and resources were dispersed across many work fronts. For instance, in the year 1957-1958 approximately 142 million pesos were spent on isolated road projects, the equivalent of about a third of the money the National Government had spent in the framework of the Plan Vial 1 from 1953 to 1958.[39] Already in 1960 the Minister of Public Works had pointed out the need to concentrate efforts on some roads of national importance (as opposed to roads of regional relevance), but by 1969 the lack of investment coordination was still seen by observers as a main problem for the Colombian road network.[40]

Second, the absence of detailed preliminary studies caused costly delays and mistakes that considerably hindered road development in the short and long terms. In the early 1950s, the lack of traffic statistics, inadequate maps, and little experience in the use of machinery, resulted in the constant revision of the projects' budgets during construction, which made planning road investments a difficult task. The Colombian road engineer Victor Archila argued in 1954 that the main defect of the Plan Vial 1 was the inadequacy of its initial budget. Planners had no knowledge of the necessary technical characteristics of each project, so they assumed they would all cost the same.[41] This, however, was not the case, as the price of each type of surface was different depending on traffic, work, and environmental conditions.[42] In addition, precise routes for the roads were not determined, and the cost of materials was based on conjecture.[43] Therefore, the Plan ended up exceeding its original budget and taking more

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[37] Road projects were also approved by decrees from the government during the years in which the Congress was closed, 1949-1957. MOP, Parsons, Brinckerhorff, Quade & Douglas, *Estudio del Transporte Nacional: Plan de Mejoramiento para los Transportes Nacionales* (Bogotá, 1962), I-31.
[38] In addition, every Departamento and Municipio had the autonomy of planning its own network, although for practical reasons this chapter focuses on the national road network.
[39] MOP, *Memoria de Obras Públicas 1958,* 15, 20.
[40] See Felstehausen, *Conceptos de Planeamiento*, 2; MOP, *Memoria de Obras Públicas 1960*, 340.
[41] For instance, they assumed that paving 1 km of road cost 20,000 pesos per km, and therefore 600 km of paving would cost 12 million pesos. Victor Archila Briceño, 'El Segundo Plan Vial', in *Anales de Ingeniería de Colombia,* 58 (August 1954), 12.
[42] Archila, 'El Segundo Plan Vial', 12.
[43] Archila, 'El Segundo Plan Vial', 12.

than ten years to complete instead of the planned three.[44] The World Bank explained the slow progress of construction in the projects it financed in the 1950s with the following reasons: ‘heavy seasonal rainfall, precipitous and unstable terrain, shortage of funds because of local inflation, and an unforeseen growth of traffic’.[45] Therefore, as construction advanced, the World Bank found that ‘more work was required and more equipment needed than originally anticipated’.[46] The Bank changed the standards of the roads themselves to respond to the increasing transport demands and constraining conditions.[47] Although the availability of technical studies improved in the 1960s with the work of foreign studies and the emergence of Colombian consulting firms, errors already made were difficult to correct given that investments in transport infrastructure were long-term and their final product could only be modified in a limited way.[48]

In addition to the problems generated from inadequate planning, the lack of technical support the MOP offered for the actual construction process also had a detrimental effect on the quality of the works. Although the MOP was not responsible for the construction of roads, it was in charge of supervising the private firms that were hired to build them, and of maintaining the roads after they were finished. The proportion of Colombian firms hired by the MOP increased during the period, but their resources and experience tended to be limited (at least at the beginning of the period).[49] Struggling with limited staff and resources, however, the MOP often neglected its supervisory role. This resulted in the construction of roads with poor technical standards, which made maintenance more difficult and

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[44] The Plan was supposed to cost 160 million pesos and to be finished in three years, by 1954 it was considered that it would cost 300 million and would take 5 to 6 years to finish. By 1958, 380 million had been spent. Archila, ‘El Segundo Plan Vial’, 12; MOP, *Memoria de Obras Públicas 1958*, 15.
[45] IBRD, IDA, ‘Appraisal of a Fourth Highway Project, Colombia’ (Washington D.C., 1961), 1.
[46] IBRD, IDA, ‘Appraisal of a Fourth Highway Project, Colombia’ (Washington D.C., 1961), 2.
[47] Changes included a reduction of maximum gradients in mountainous terrain, reducing the severity of curves, increase in the width of the finished grade and the paving, higher types of surfacing because of weather conditions and thicker bituminous surfaces to carry heavier traffic loads. IBRD, IDA, ‘Appraisal of a Fourth Highway Project, Colombia’ (Washington D.C., 1961), 3.
[48] Felstehausen, *Conceptos de Planeamiento*, 2.
[49] In 1960, there were about 200 Colombian construction firms, having each no more than two or three machines at their disposal, and a low average of marginal monthly investment. In 1965, the budgets of small firms usually went from 200,000 to 400,000 pesos per month and, given the high demands, if works were to be finished within ‘reasonable timelines’, firms capable of keeping an investment rhythm of more than 1 million pesos per month were needed – which made hiring foreign firms necessary for large projects. By 1970, all construction in the World Bank road project included in that year’s loan was being carried out by Colombian contractors. Yet, the Bank thought more room could be given to foreign contractors as it considered the Colombian contracting industry could be strained by handling this project on top of the ongoing work. ACIC, *Quinto Congreso*, 104-105; IBRD, IDA, ‘Appraisal of the Sixth Highway Construction Project, Colombia’ (Washington D.C., 1970), 10.

demanding.[50] Moreover, although the MOP had published manuals about certain aspects of road construction (such as geometrical standards, how to determine the best route and how to build bases and different surfaces, amongst others) from the beginning of the century and especially after the 1920s, by 1950 there were no established methods to verify the quality of materials or the works.[51] The first volume presenting a complete description of norms and specifications for road construction was published in 1966 and was based on standards from the American Bureau of Public Roads (BPR).[52] Apart from the fact that these publications were scarce, there is little evidence of the impact they had on road planning and construction. It seems they had a limited application given that in the 1970s many roads were carrying about three to five times more traffic than they were designed to bear.[53]

In addition, the MOP did little to protect the emergent Colombian construction firms from going bankrupt. During the 1950s and 1960s, having a construction firm in Colombia was highly risky and improving the chances of having a successful venture became a priority for the Colombian Association of Engineering Contractors (Asociación Colombiana de Ingenieros Contratistas, ACIC), founded in 1954.[54] Most construction contracts were made by unit price, which means the MOP paid firms for each project based on estimated quantities of items (e.g. earthworks, bases, paving, etc.) and their unit prices. If the estimate was not accurate, the project exceeded the budgeted cost and it was the contractor's responsibility to cover for it – and this was a common phenomenon. As firms acquired more experience they were more likely to make precise estimates; currency devaluation, however, meant that unit prices became obsolete in a short amount of time.[55] This was particularly problematic for construction firms given the long timelines of their projects.[56] In 1963, the ACIC created a few formulas to readjust the unit prices taking into account factors such as machinery and the prices of materials, labour costs and administration fees.[57] Although the MOP approved the use of the formulas, factors such as speculation and false scarcity could still put the small

[50] AGN, AO, MOPT, División Ingeniería de Materiales, 51-15-209, Informes – Planos – Laboratorio Central – Ley 4 de 1966 – Decreto No. 248/66 (1962-1968), Letter from Reinaldo Perdomo, Jefe Rama Técnica to Alfredo D. Bateman, Director del Ministerio (1 July 1965).
[51] Fernando Sánchez Sabogal, 'Notas Para Una Crónica de las Especificaciones de Construcción de Carreteras en Colombia', in Academia Colombiana de Historia de la Ingeniería y de las Obras Públicas, *Apuntes Para la Historia de la Ingeniería en Colombia*, VIII (2012-2013), 77-79.
[52] Sánchez Sabogal, 'Notas Para Una Crónica', 80.
[53] Sánchez Sabogal, 'Notas Para Una Crónica', 81.
[54] ACIC, *Quinto Congreso*, President's opening statement, 23.
[55] ACIC, *Quinto Congreso*, 119.
[56] ACIC, *Quinto Congreso*, 119.
[57] Carlos Obando V., 'Reajuste de los Precios Unitarios en los Contratos del Ministerio de Obras Públicas', in *Anales de Ingeniería de Colombia*, 68 (April-June 1963), 22.

construction firms at risk.[58] In addition, construction contracts protected the state if the contractor failed to finish works on time (or at all). This situation was very common due to the lack of adequate preliminary studies, and often resulted in the bankruptcy of the firms and/or the abandonment of the work.[59]

Therefore, although the state was expecting to promote railway traffic and expand the road network, it failed to do so, thus making maintenance and improvements the processes that ultimately allowed the increase of road traffic. This was also possible due to the loans from the World Bank, as road improvements (and not only construction) featured in the projects it financed. All of these included some type of road improvement (whether it was reconstruction or just paving); some of them included support for the implementation of more effective maintenance schemes; and two loans were issued to purchase machinery and equipment to be used for maintenance.[60] Although new construction was important, improvements sometimes were first on the agenda. For instance, the first road loan in 1951 had the objective of building 115 km of new roads and reconstructing 2,906 km of existing ones.[61] Another example is the road project of 1970, which envisaged the construction of a 9.5 km road and a bridge across the Magdalena River but, above all, provided funds to pave 1,600 km of road, as well as to upgrade a stretch of the road to Buenaventura (parallel to the Ferrocarril del Pacífico).[62]

<u>Improving and maintaining the Colombian road network</u>

[58] ACIC, *Quinto Congreso*, 121.
[59] Francisco Manrique S., 'Asociación de Ingenieros Contratistas. La Industria de la Construcción de Obras Públicas', in *Anales de Ingeniería de Colombia,* 74 (April-June 1965), 13.
[60] IBRD, 'Report and Recommendations of the President to the Executive Directors on the Proposed Loan to the Republic of Colombia' (Washington D.C., April 1951); IBRD, 'Appraisal of Revised Highway Project in Colombia' (Washington D.C., September 1953); IBRD, 'Report and Recommendations of the President to the Executive Directors on the Proposed Loan to the Republic of Colombia' (Washington D.C., May 1956); IBRD, 'Report and Recommendations of the President to the Executive Directors on a Proposed Loan and a Proposed Development Credit to the Republic of Colombia for a Road Project' (Washington D.C., August 1961); IBRD, 'Report and Recommendations of the President to the Executive Directors on a Proposed Loan to the Republic of Colombia for the Fifth Highway Project' (Washington D.C., July 1968); IBRD, 'Report and Recommendations of the President to the Executive Directors on a Proposed Loan to the Republic of Colombia for the Sixth Highway Project' (Washington D.C., April 1970).
[61] IBRD, 'Report and Recommendations of the President to the Executive Directors on the Proposed Loan to the Republic of Colombia' (Washington D.C., April 1951), 2-3.
[62] IBRD, 'Report and Recommendations of the President to the Executive Directors on a Proposed Loan to the Republic of Colombia for the Sixth Highway Project' (Washington D.C., April 1970), 3.

The objectives and particular challenges

We have seen that maintenance and improvements were the tasks which kept roads passable to a growing amount of traffic, but what did they entail? There were two kinds of maintenance work: routine and special. Routine maintenance comprised patching and correcting small surface defects, cleaning and repairing drainage works, fixing the traffic signs and other small improvements. Special maintenance corresponded to more expensive and demanding works that were needed to ensure the stability and functioning of the road, such as rebuilding the bases and the surfaces.[63] Improvement works could also include paving, which would often require considerable reconstruction depending on the quality of the maintenance the road had received after being built, and also depending on the technical specifications they had when they were first finished. During this period, a considerable amount of paving took place. Paved surfaces were mostly made of asphalt.[64] The government saw paving as a way of reducing future maintenance costs.

As Graph 5.5 shows, although the length of unpaved roads surpassed paved roads throughout the period, the length of paved roads went from 100 km in 1950 to about 4,800 km by 1970.[65] However, this still represented only about 24 per cent of the total length. By 1969, paved roads were still a minority and there were no continuously paved roads between the centre of the country and the coasts.[66]

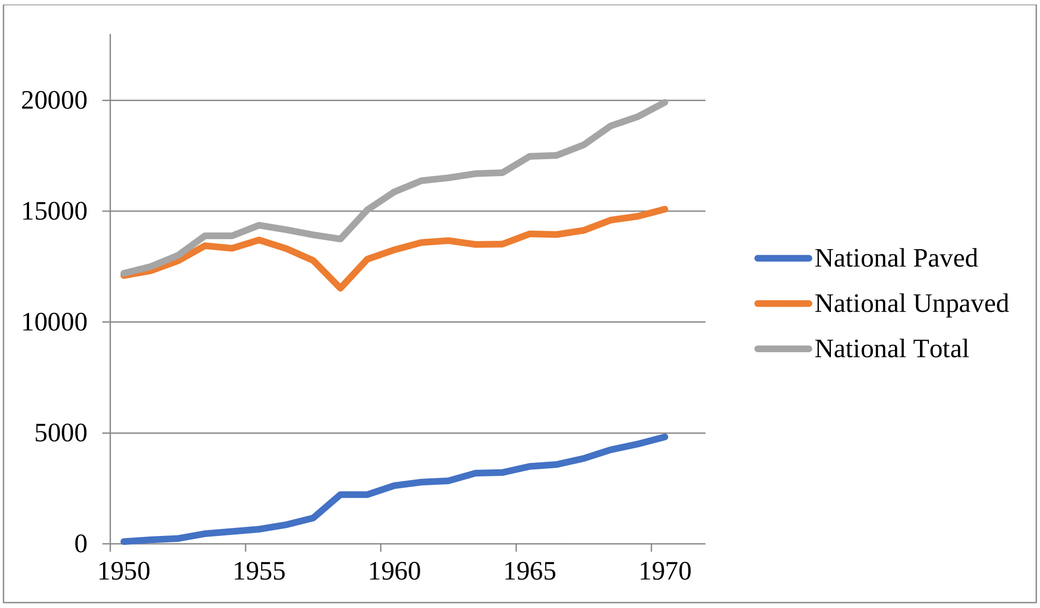
Graph 5.5 Evolution of the national road network in Colombia, 1950-1970 (km)

[63] AGN, AO, MOPT, Secretaría General, 166-27, Compañía Mexicana de Consultores en Ingeniería SA (COMEC) and Frederic Harris Engineering Corporation, *Misión Técnica COMEC-HARRIS, Información al Señor Ministro Acerca de las Necesidades de Equipo para la Conservación de Carreteras a Cargo del Ministerio* (Bogotá, 1969), 3 (hereinafter: *Misión Técnica COMEC-HARRIS*).

[64] The high prices of concrete surfaces had limited its use to some major airports and streets in Bogotá, Medellín and Cali from the 1930s to the 1960s. Other factors that seem to have had an important influence in the choice of asphalt as the preferred paving surface in Colombia are the support of the state to petroleum exploitation with the creation of the Colombian Petroleum Enterprise (known today as Ecopetrol) and the nationalisation of the Tropical Oil Company's concession in 1951, as well as the introduction of Esso and Texaco lubricants and other petroleum products from the mid-1950s onwards. By 1938, Colombia was producing over 200,000 tons of cement per year. Anon., '145 Años de Historia de los Pavimentos de Concreto', in *Noticreto* 100 (May-June 2010), 88; Hernando Vargas Caicedo and Juan Pablo Ortega Samper, '100 Años de Cemento en Colombia, Notas Sobre Su Origen', in *Noticreto* 100 (May-June 2010), 61; Ecopetrol, https://www.ecopetrol.com.co/wps/portal/es/ecopetrol-web/nuestra-empresa/sala-de-prensa/publicaciones/otras-publicaciones/cronica-de-la-concesion-de-mares/reversion-de-la-concesion-de-mares (26/04/2018); Esso Mobil Colombia, https://combustiblescolombia.com/the-transition (26/04/2018).

[65] Pachón and Ramírez, *La Infraestructura de Transporte en Colombia,* Anexo II.37

[66] Felstehausen, *Conceptos de Planeamiento*, 17.



Source: Based on data from Pachón and Ramírez, *La Infraestructura de Transporte en Colombia*, Anexo II.37.

Therefore, most of the network was unpaved, which implied particular kinds of obstacles for maintenance. Unpaved roads were mostly made of gravel or crushed rock, sometimes stabilised with cement or asphalt. Engineers used different terms to talk about unpaved roads: earth roads, 'motorable' ('carreteable'), or roads of 'superficie afirmada', but for practical reasons (and because the data usually only differentiates between paved and unpaved surfaces), I will use the term 'unpaved' to refer to all these types of surfaces. Unpaved roads were distinguishable from mule tracks, often known as 'caminos de herradura', because their construction involved the use of engineering knowledge and techniques in order to allow the traffic of motor vehicles. Given the important proportion of unpaved roads, especially those made of gravel, in 1966 the road engineer Guillermo Caro Mendoza published in *Anales* an article explaining the major problems around the maintenance of gravel roads, and the methods to solve them based on his experience. As in FWA, corrugations were a recurrent problem (see Chapter 3), but Colombian gravel roads also had other particular defects such as such the lack of verges and poor surface conditions resulting from the use of inadequate materials (e.g. aggregates that were too large, lack or excess of binders, deficient grading, amongst others).[67]

[67] Caro, 'Mantenimiento de Carreteras', 111.

Whether paved or not, however, roads were badly prepared to cope with the growth of traffic. First, the number of vehicles not only increased, their weight did as well, and roads were not designed to bear these ever-heavier loads. The total number of vehicles used in Colombia multiplied by five times from 1949 to 1970, and goods vehicles occupied an increasingly larger proportion of the traffic.[68] The number of lorries multiplied by about three times from 1949 to 1970, going from 16,540 to 60,442.[69] The capacity of the lorries themselves doubled. In the 1950s, the average capacity of a lorry in Colombia was about 3 ton, in 1963 it rose to about 4.6 ton, and in 1969 it was about 6 ton.[70] Although lorries were a significant part of the vehicle fleet, they were not the only vehicles used to carry goods. Jeeps and dumper trucks went from representing about 17 per cent of the fleet in 1950, to 38 per cent in 1970, i.e. more than any other category of vehicle, including lorries (see Table 5.1). However, the real problem with the increase of heavy traffic was that many roads were carrying significantly more traffic than they were designed to bear. For instance, in 1971, 70 per cent of the vehicles on the road from Armenia to Ibagué (considered one of the most important roads in the country since it connected Bogotá to Cali and thus the Pacific Ocean) were heavy lorries, and the road was carrying over 200 per cent of its original bearing capacity.[71] Moreover, the high proportion of unpaved roads that were carrying heavy vehicles made maintenance works very difficult. In 1960, although a little over half of the unpaved roads were carrying less than 250 vehicles per day, the rest of the unpaved roads had to bear from 250 to 2,000 vehicles per day.[72]

Table 5.1 Motor vehicle fleet by type of vehicle in Colombia, 1950-1970 (in percentage)

Year	Automobiles	Lorries	Buses	Jeeps, dumper trucks
1950	42	28	12	17
1960	40	24	8	28
1970	32	20	10	38

[68] Pachón and Ramírez, *La Infraestructura de Transporte en Colombia*, Anexo II.40.
[69] Pachón and Ramírez, *La Infraestructura de Transporte*, Anexo II.40.
[70] Pachón, 'La Infraestructura de Transporte', 345.
[71] Durán, 'Análisis de la Situación', 18.
[72] Pachón and Ramírez, *La Infraestructura de Transporte*, Cuadro II.23.

Source: Based on data from Pachón and Ramírez, *La Infraestructura de Transporte en Colombia*, 344.

In addition, the damage inflicted on the roads by heavy vehicles was exacerbated by the unorthodox use of the fleet. Vehicles were used about three years longer than it was considered safe (sometimes more) due to the high taxes on the imports of vehicles and their spare parts – particularly in the case of lorries.[73] The common phenomenon of overloading also increased the damage that heavy vehicles caused to the surfaces as it facilitated the formation of potholes during the rains and of corrugations in the dry season. By 1970, the government had not managed to enforce weight regulations on lorries and a prompt enforcement of the norms seemed unlikely.[74] The use of hybrid vehicles to carry both passengers and freight (often called ‘chivas’) also contributed to intensify the wear and tear of the surfaces, as they were not designed to carry heavy loads.

The Colombian tropical climate and rugged topography also made road maintenance a challenging endeavour.[75] For instance, in 1958 the MOP stated that the ‘excessive influence’ of meteorological factors was one of the potential causes of the rapid deterioration of asphalt roads, as damages were appearing very fast even on roads that had been built with optimal technical procedures.[76] Moreover, the high temperatures of certain regions were severely damaging the tyres of motor vehicles to the point that some transport companies had decided to travel only at night on certain routes.[77] Yet, perhaps the environmental factor that most affected road works was the scarcity of adequate construction materials. In an interview with Enrique Ramírez Romero, former President of the Sociedad Colombiana de Ingenieros (SCI) and former intern at the Central Materials Laboratory in Bogotá, he stated that the soil in many areas of the country, despite being very fertile, was not adequate for road works.[78] Therefore, large quantities of sand, rock and other materials had to be moved, making the

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[73] According to a study commissioned by the MOP in 1962, a public transport vehicle should only be used for a maximum of five years, but in Colombia buses were used for an average of eight years. The study estimated that if old models were put out of circulation, this would mean retiring almost 70 per cent of public service vehicles. The lorry fleet was particularly old: in 1967 the fleet of lorries was considerably older than the fleet of buses and automobiles. MOP, Parsons, Brinckerhorff, Quade & Douglas, *Estudio del Transporte Nacional: Plan de Mejoramiento para los Transportes Nacionales* (Bogotá, 1962), I-29; Pachón, ‘La Infraestructura de Transporte’, 347.
[74] Weight regulations dated from 1955: 8.2 m tonnes for single axles and 14.5 m tonnes for tandem axles. IBRD, IDA, ‘Appraisal of the Sixth Highway Construction Project, Colombia’ (Washington D.C., April 1970), 12.
[75] These factors also affected construction prices. As an example, in 1969, the construction price of a kilometre of paved road in humid mountainous terrain could be about three times the cost of one in well-drained flat terrain. Felstehausen, *Conceptos de Planeamiento*, 15.
[76] MOP, *Memoria de Obras Públicas 1958*, 37.
[77] MOP, *Memoria de Obras Públicas 1958*, 37.
[78] Enrique Ramírez Romero, Interview by Author (Bogotá, 16 January 2018).

transport of materials one of the most expensive items of a project. For instance, in mountainous areas it was often very difficult to find good rock, and while in some regions soils could have potentially been used, important resources would have been necessary to make them ready to use (e.g. crushing or stabilising). On top of that, given the huge diversity of soils, considerable time and money were also needed to determine the soil properties and ensure they were fit for purpose. Although the difficulty of accessing materials affected construction more than maintenance, it was still an essential part of improvement works, especially when they required significant reconstruction.

Nonetheless, the difficulties of keeping the roads passable were ultimately determined by the way roads were built, used, and maintained. Traffic and environmental conditions only exacerbated the problems that technical structural deficiencies caused. Inadequate design, cleaning and maintenance of roads played an important role in the acceleration of deterioration processes. In 1971, the MOP lamented that almost no attention had been paid until then to the control of water, the exploitation of forestry resources, and the inadequate use of land, leading to the exacerbation of destructive processes.[79] For instance, the lack of vegetation along the roads resulted in erosion and landslides, which could result in river sedimentation, and the associated increase of flood risk and reduction of water quality.[80] In the 1960s, most unpaved roads also suffered from a lack of verges, which presented a risk not only for the safety of the users, but also for the adequate drainage of the roads and therefore for the stability of the road itself.[81] In addition, ditches were neglected and often became blocked by crops, weeds, sedimentation and even landslide deposits.[82] Moreover, inadequate drainage considerably increased maintenance costs. For instance, in 1969 it was considered that correcting road design and drainage would cut in half the cost of maintenance per kilometre of road, regardless of whether the road was paved or not.[83] The combination of construction defects and maintenance neglect over time often made expensive emergency works necessary after heavy rains. For example, the rainy season of 1970 caused about 500 million pesos worth of damage and some roads were only opened to traffic after three months of works that were not even considered permanent solutions.[84]

[79] Durán, 'Análisis de la Situación', 18.
[80] Durán, 'Análisis de la Situación', 18.
[81] Guillermo Caro Mendoza, 'Mantenimiento de Carreteras en Grava', in *Anales de Ingeniería de Colombia*, 75 (April-June 1966), 112.
[82] Caro, 'Mantenimiento de Carreteras', 111. Peasants also sometimes used ditches to grow crops causing landslides due to the removal of the impervious vegetation layer. *Misión Técnica COMEC-HARRIS*, 175.
[83] Felstehausen, *Conceptos de Planeamiento*, 15.
[84] Durán, 'Análisis de la Situación', 18.

The modernisation of maintenance: new knowledge and the existence of a Latin American engineering network

To make its deficient road network fit to respond to the transport demands, the Colombian government considered it necessary to modernise its maintenance activities. An essential part of this process was the availability of specialised engineers who could understand and adapt modern engineering techniques to the Colombian context. This was possible because from the 1950s onwards, Colombian universities with engineering programmes such as the National University of Colombia, the Javeriana University, and Los Andes University in Bogotá, started introducing more specialised engineering programmes.[85] Moreover, these institutions, along with others such as the Colombian Institute of Technical Norms (Instituto Colombiano de Normas Técnicas), offered short courses on soil properties, types of paving surfaces, and paving methods design, amongst other related topics.[86] These courses usually took place in Bogotá and the speakers were either American experts or Colombian engineers with an American degree from the Massachusetts Institute of Technology, the Colorado School of Mines, or the Universities of Harvard, Pittsburgh and Illinois.[87] Although the government did not offer these courses, the MOP received invitations to them and it seems it encouraged members of its staff to attend.[88]

As these courses and the education of Colombian engineers suggest, American norms and methods were highly influential in Colombia. In the MOP's publications determining construction and maintenance norms, most of the references were American (e.g. Highway Research Board, the American Association of State Highway Officials, and different states' road authorities).[89] For instance, in 1965, the MOP published a book containing methods, norms and technical specifications for road construction and maintenance in which the American influence was evident.[90] The chapter on flexible paving surfaces, for example, referenced the development of design methods in the US after the Second World War.[91] The publication stated how during the war American engineers determined the thickness of paving surfaces through appearance and estimations, but that given the need to build a great length

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[85] The Mines School in Medellín was also important.
[86] AGN, AO, MOPT, División Ingeniería de Materiales, 51-15-209, Informes – Planos – Laboratorio Central – Ley 4 de 1966 – Decreto No. 248/66 (1962-1968), Correspondencia.
[87] AGN, AO, MOPT, División Ingeniería de Materiales, 51-15-209, Informes – Planos – Laboratorio Central – Ley 4 de 1966 – Decreto No. 248/66 (1962-1968), Correspondencia.
[88] AGN, AO, MOPT, División Ingeniería de Materiales, 51-15-209, Informes – Planos – Laboratorio Central – Ley 4 de 1966 – Decreto No. 248/66 (1962-1968), Correspondencia.
[89] See for e.g. MOP, *Especificaciones Normales Especificaciones Normales para la Construcción de Carreteras y Calles* (Bogotá, 1955).
[90] MOP, *Normas de Diseños y Especificaciones de Materiales para Carreteras* (Bogotá, 1965).
[91] MOP, *Normas de Diseños y Especificaciones*, D120.

of roads with military purposes, the US lead several investigations into road design methods.[92] However, since these methods were still relatively recent by the mid-1960s, there was no consensus about which was the best. For example, to decide the method to measure soil bearing capacity, the Colombian MOP carried out its own research taking into account local materials and conditions, and after comparing different methods, such as those used in California, Kansas, Oregon and Wyoming, it concluded that the CBR was the one that should be adopted.[93]

Soil stabilisation is another example of the American influence in road engineering in Colombia, where the scarcity of funds made this method particularly attractive (see Chapter 2).[94] Soil-cement was the most widely known stabilisation method in the country in the 1960s, and it was first used in the US in the 1920s.[95] By 1965, experience in Colombia had shown that soils stabilised with cement constituted an excellent surface capable of withstanding high volumes of traffic if it was properly protected by a layer of bituminous material.[96] For Colombia's traffic conditions, having about 50 per cent of heavy vehicles, it was proven that a base stabilised with cement was able to bear traffic of 1,000 vehicles per day without suffering major damages.[97] However, this was also the most expensive method of stabilisation in the country, so it was exclusively used in roads of heavy traffic or that were so important that it was likely that they will develop heavy traffic.[98] Great Britain also used soil stabilisation extensively, particularly in its African colonies, and Colombian engineers were well aware of the findings of the RRL on this and other topics, as we will see below.

Although the US was the main referent in terms of road development, Colombian engineers also looked elsewhere for valuable knowledge and techniques. Great Britain, and in particular the Overseas/Tropical Section of the RRL, was an important source of knowledge for Colombian engineers.[99] Due to the RRL's research on roads in Central and East Africa, engineers in Colombia found relevant its work on the comparison between transport costs on

92 MOP, *Normas de Diseños y Especificaciones*, D120-2.
93 See Chapter 2. MOP, *Normas de Diseños y Especificaciones*, D120-2.
94 MOP, *Normas de Diseños y Especificaciones*, D150-1.
95 MOP, Normas de Diseños y Especificaciones, D150-5.
96 Hiram B. Preston, 'La Estabilización de Suelos Como Una Solución al Problema de Mantenimiento de las Carreteras Colombianas', in *Anales de Ingeniería de Colombia*, 74 (September-October 1965), 33.
97 Preston, 'La Estabilización de Suelos', 33.
98 Preston, 'La Estabilización de Suelos', 33.
99 France and Germany were also significant influence. For instance, French hydraulic laboratories were sometimes consulted in complicated cases, such as for the Ciénaga-Barranquilla road. In addition, a German mission visited the Central Laboratory in 1967 to assess its efficiency. AGN, AO, MOPT, División Ingeniería de Materiales, 4-2-418, Carretera Ciénaga-Barranquilla, Informes – Planos (1956-1965); AGN, AO, MOPT, División Ingeniería de Materiales, 51-15-209, Informes – Planos – Laboratorio Central – Ley 4 de 1966 – Decreto No. 248/66 (1962-1968).

paved and unpaved surfaces. For instance, in an article in 1965, the engineer Guillermo Caro mentioned an article written by R.S. Millard and R.S.P. Bonney from the RRL on the operation costs of buses and lorries on different surfaces in Africa.[100] The conclusion Caro extracted from this article was that transport costs varied more between badly and properly maintained unpaved roads, than between paved and well-kept unpaved roads. Therefore, an unpaved road, if properly maintained, could bring similar benefits than a paved road, for a considerably lower price.[101] Although this research originated in Great Britain, it is worth noting that in this particular case, the article was accessed via *Road International* (the journal belonging to the originally American-based International Road Federation).[102]

Furthermore, although American and European experts were major references, the technical specifications of countries such as Mexico, Argentina, and Chile were also consulted for the elaboration of local maintenance and construction norms.[103] Sebastián Ospina, the most prominent Colombian advocate of roads, and of motorable unpaved roads in particular, acknowledged that he had first encountered 'carreteables' for public service in Argentina in the 1920s. At the time, Ospina travelled to Buenos Aires to attend the first Pan-American Highway Congress in 1925, taking the opportunity to travel across Argentina and other South American countries. In Argentina, in the mountainous area of Sierras de Córdoba, he saw for the first time roads that were 'less about science' and more about 'daring to vanquish the difficulties of a rugged topography'.[104] He then went onto Brazil and Venezuela, where he learned that there were thousands of kilometres of 'carreteables' which were maintained 'with such care that the lack of rigour in their specifications was forgotten'.[105] Although he might be exaggerating the success of these countries to convince his colleagues of the desirability of motorable unpaved roads, it is telling that his first encounter with this approach to road building took place in other South American countries. It is also worth noting that the very opportunity that prompted his trip (the Pan-American Highway Congress) was orchestrated by the US in the first place.

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[100] R.S. Millard and R.S.P. Bonney, 'The Costs of Operating Buses and Trucks on Roads with Different Surfaces in Africa', in *Road International* (June, 1965), 18-23, 26-27, quoted in Caro, 'Mantenimiento de Carreteras', 115.
[101] Caro, 'Mantenimiento de Carreteras', 115.
[102] This article was quoted in World Bank reports in 1967 and as late as 1987, when it was still considered valuable to discuss the economic appraisal of transport projects despite giving 'out-of-date information on vehicle operating costs'. IBRD, Hans A. Adler, *Sector and project planning in transportation* (Washington D.C., 1967); IBRD, Hans A. Adler, *Economic Appraisal of Transport Projects. A Manual With Case Studies, Revised and Expanded Edition* (Washington D.C., 1987), 327.
[103] MOP, *Especificaciones Normales*, Part 1.
[104] Ospina, 'Especificaciones para el Trazado', 1265.
[105] Ospina, 'Especificaciones para el Trazado', 1265.

In addition, Mexico and Argentina seem to have had a particularly influential role in Colombia in terms of road engineering and administration. For instance, Mexico's experience was referenced when creating a programme of financing low traffic rural roads ('caminos vecinales'). In 1961, *Anales* published an article on Mexico's system of 'Caminos Vecinales' with the objective of extracting lessons from the problems they encountered, such as the poor road conditions resulting from the expectation that nearby inhabitants would take care of maintenance themselves.[106] In 1960, Colombia created its Fondo Nacional de Caminos Vecinales, independent from the MOP. Although the fund's progress was very slow and only took off in the 1970s and 1980s, thirty years after its creation Mexico was still considered a pioneer and an example of this type of road financing method.[107] Apart from the example of the mountain 'carreteables', Argentina's influence can be illustrated with the use of a document produced by the Argentinian Dirección Nacional de Vialidad as the basis for a Colombian compilation of road terminology in 1968.[108] Concerned about the diversity of terms used in road construction and maintenance, Argentinian engineers put together a list of definitions of the main road engineering terms used in different countries, including their equivalent in English, French and sometimes Portuguese. The Colombian MOP adapted this document including some suggestions made by the SCI. For instance, to define maintenance, after considering the words used for it in different languages and countries (e.g. maintenance in English, 'entretien' in French, 'mantenimiento' in Nicaragua), the MOP decided to use 'conservación', the term also used in Argentina (since they thought 'mantenimiento' was related to sustenance).[109] Yet, the MOP adopted a definition of maintenance proposed by the SCI: 'works necessary so that any type of road or structure maintains conditions of adequate service', thus moving away from the definition accepted by the 2nd Meeting of the Technical Commission of Terminology of the Pan-American Highway Congress (i.e. 'works done to avoid that any road or structure loses permanently the characteristics of the built work').[110]

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[106] Anon. 'Los Caminos Vecinales de México', in *Anales de Ingeniería de Colombia*, 67 (August-September 1961), 16.

[107] The Fund provided on average 66.7 million pesos per year in the 1960s, while in the 1970s, it provided on average 252.7 million pesos per year. However, there is little data on the actual progress of the Caminos Vecinales. Broadly speaking, in its first 30 years of existence, the programme built and did improvement works on almost 31,000 km of unpaved roads. MOP, *Fondo Nacional de Caminos Vecinales, 1986-1990. 30 Años* (Bogotá, 1990), 12, 19.

[108] AGN, AO, MOPT, Secretaría General, 197-32, Términos de la Sección 2 – Construcción y Conservación de Obras Viales (1968).

[109] AGN, AO, MOPT, Secretaría General, 197-32, Términos de la Sección 2 – Construcción y Conservación de Obras Viales (1968), 33-34.

[110] AGN, AO, MOPT, Secretaría General, 197-32, Términos de la Sección 2 – Construcción y Conservación de Obras Viales (1968), 33-34.

The modernisation of maintenance: new machines and how to work with them

The other significant transformation that maintenance underwent in this period was the acceleration of mechanisation. Indeed, one of the most important investments made with the money destined for maintenance (from both the National Government and the World Bank loans) was the expansion of the machinery. As the MOP was struggling to keep up, the lack of machinery was identified as one of the most determinant obstacles for the development of the road network.[111] For the MOP, in 1945, the purchase of a bulldozer Caterpillar TD7 (considered to be as efficient as 80 workers) presented the advantage of not demanding paid holidays, sick leave, costly safe and hygienic working conditions, life insurance or severance packages.[112] In the 1950s, the first loan from the World Bank involved the acquisition of heavy equipment, given the mountainous terrain and the consequent need to move considerable amounts of material.[113] By 1958, the MOP had at its disposal 206 motor-graders, 242 tractors, 660 dumper trucks, and 145 rollers, amongst others.[114] Ten years later, in 1969, the MOP had 377 motor-graders, 32 agricultural tractors, 250 crawler tractors (Caterpillar D5 or alike), 1,086 dumper trucks, and 197 rollers, amongst others.[115] Road construction was also mechanising rapidly during this period, but given that it was carried out by private firms, finding information and figures is difficult. In 1957, however, the MOP gave an estimate of the number of machines owned by private construction companies. Their fleet included 177 bulldozers, 53 motor-graders, 160 tractors, and 503 dumper trucks, which was comparable to the MOP’s fleet at the time.[116] The majority of the machines used in Colombia were American. Indeed, when calculating the price of any road works, to determine how much investment was required for machinery and/or spare parts, only the price of the certified dollar and the American price indexes were considered, as most machines came from the US.[117] This was in great part due to the fact that the money available to purchase machinery came from the World Bank, and buying American brands was often a condition of the loans. Therefore, although Ruston (UK), Massey Ferguson (Canada) and Komatsu (Japan) machines could be found, Caterpillar was ubiquitous, and other American brands were the

[111] Labourers had benefits corresponding to 50 per cent of their daily wage, which was considered excessive by the Ministry of Public Works in 1945. MOP, *Memoria de Obras Públicas 1945,* IV; MOP, *Memoria de Obras Públicas 1945,* XIV, 24.
[112] MOP, *Memoria de Obras Públicas 1945*, XIV, 24.
[113] IBRD, IDA, ‘Appraisal of the Sixth Highway Construction Project, Colombia’ (Washington D.C., 1970), 10.
[114] MOP, *Memoria de Obras Públicas 1958*, 44.
[115] *Misión Técnica COMEC-HARRIS*.
[116] MOP, *Realizaciones de Obras Públicas Nacionales. 5 de Abril-Julio de 1957: Informe Gráfico que Rinde el Ministerio de Obras Públicas de las Obras Ejecutadas de Agosto de 1954 a Mayo de 1957* (Bogotá, 1957), 131.
[117] ACIC, *Quinto Congreso*, 121.

norm (e.g. Barber Greene, Austin, Bucyrus, International, Allis-Chalmers).[118] Similarly, General Motors, Dodge and Ford were the most common brands of lorries.[119]

Although the number and type of machines used in Colombia were similar to the ones carrying out maintenance work in French West Africa, there was a big difference: the dumper truck. First created in the US in the 1930s, the motorised dumper truck was designed to transport heavy materials replacing dump railcars and wagons.[120] After the Second World War, new models of these trucks were created to be able to carry heavier loads by increasing the size and the number of wheels, amongst other modifications.[121] Other ‘off-highway’ trucks (i.e. too heavy and wide to circulate on most public roads) were also created in the 1960s, such as the articulated dumper truck.[122] Dumper trucks were used extensively in Colombia: they were the most numerous piece of equipment used. These vehicles facilitated the transportation of heavy materials over long distances, an expensive but necessary effort due to the types of rock and soil that were most frequent in the country (as previously mentioned). However, Colombia did not use the largest vehicles available on the market: the trucks used in the late 1960s were able to carry 3 to 5 Yd^3, while trucks carrying up to 10 Yd^3 were already available since at least the early 1960s.[123] This is not surprising, as the larger and heavier the vehicles, the wider, harder, and more stable the roads needed to be.

The acquisition of new machines required new knowledge from the workers. During the 1950s and the early 1960s, most road workers had learned by doing, working alongside foreign and national engineering firms.[124] In 1957, the creation of the National Vocational Training Agency (‘Servicio Nacional de Aprendizaje’, or SENA), with the support of the International Labour Organisation, marked an important moment in the history of labour in the country as the institution aimed to provide technical education in the fields of agriculture, mining, commerce, and industry. The SENA generated the first generation of Colombian topographers, for example, and thus played an important role in the modernisation of road development.[125] However, it is likely that the SENA’s impact was only felt at least a few

[118] See list of machinery used in the construction of the Ciénaga-Barranquilla road in 1965, AGN, AO, MOPT, Interventorías, 4-65-43, Carretera Ciénaga-Barranquilla, Adicionales de Actas de Recibo de Obras – Cuadros Informes (1966).
[119] AGN, AO, MOPT, Interventorías, 4-65-43, Carretera Ciénaga-Barranquilla, Adicionales de Actas de Recibo de Obras – Cuadros Informes (1966).
[120] Historical Construction Equipment Association http://www.hcea.net/page-1553666 (08/06/2018)
[121] Historical Construction Equipment Association http://www.hcea.net/page-1553666 (08/06/2018)
[122] World Highways http://www.worldhighways.com/categories/earthmoving-excavation/features/versatile-articulated-dump-truck/ (08/06/2018)
[123] Historical Construction Equipment Association http://www.hcea.net/page-1553666 (08/06/2018)
[124] Enrique Ramírez Romero, Interview by author (Bogotá, 16 January 2018).
[125] Enrique Ramírez Romero, Interview by author (Bogotá, 16 January 2018).

years after its foundation. The MOP also played a role in the formation of machine operators and mechanics. The following picture illustrates some of this training (Figure 5.2).

Figure 5.2 Mechanics of the Ministerio de Obras Públicas in training, ca 1957

[Picture removed from ethesis version on copyright grounds]

Source: Mechanics training on a Caterpillar D7. MOP, *Realizaciones de Obras Públicas Nacionales,* 135.

Workers were not the only ones that needed to learn how to work with machines. Engineers and administrative staff had to deal with questions such as how many machines were needed, of what kind, and how to plan their necessary maintenance and repairs, amongst many others. This was not a straightforward process. For instance, the MOP often struggled with the fact that their machines had diverse models, which made the provision of spare parts difficult.[126] In 1955, the engineer Gustavo Uribe published an article on the mechanisation of road maintenance, focusing on how to organise the works. He suggested dividing the work between units that were adapted to particular kinds of work (and not have *one* type of unit dealing with different kinds of tasks).[127] Learning how to work with machines meant

[126] *Misión Técnica COMEC-HARRIS*, 142.

[127] He differentiated between eight different types of unit organisation going from the gangs with no machines (mostly in charge of repairing potholes and cleaning culverts and ditches over about 2 to 5 km of road), to the flying units – a temporary organisation that operated only in times of high demand, like the rainy season, performing urgent works with the help of a motor grader, dumper trucks, a loader, and a dozen workers and operators. Another type of unit, the local one, was the most common kind of group. In charge of the routine maintenance of the same road section all year long (about 100 km long), the local units comprised each in their simpler version only three men, one lorry and its driver. Gustavo Uribe, 'La Mecanización de las Operaciones de Conservación de Carreteras', in *Anales de Ingeniería de Colombia,* 59 (January 1955), 34.

understanding that the quality of mechanised maintenance did not depend solely on the availability of the machines. First, for optimal results, each machine should be used for particular purposes. For instance, bulldozers, more common in construction than in maintenance works, were only used to collect aggregates and additional materials as part of the surface improvement process.[128] Second, keeping a machine and its operator together, working as a team, was considered advantageous. This work organisation improved the quality of the work over time and minimised damage to the machines.[129] Nevertheless, this was often not possible, given that there were more units than machines and often 1 motor-grader carried out work on more than 200 km of road.[130] This division of tasks between different types of units was inspired by the example of different American road departments.[131] In the 1950s, there seems to have been a debate in the US around how much ground one maintenance unit should cover. Maintaining a wide terrain facilitated a better use of equipment, while staying local gave the workers a sense of belonging and appreciation, as well as improved efficiency because they would get to know the terrain in more detail.[132] Uribe sided with the local approach given the long-term benefits it appeared to offer, even if the other one seemed cheaper at first.[133] For Colombian engineers to apply this type of work organisation, however, many adaptations were necessary. One of the most prominent differences was the scarcity of specialised road building and maintaining machines, which resulted in the adaptation of other, more accessible ones, such as dumper trucks and tractors.[134]

The limits of maintenance: the administrative obstacles

Despite the efforts to modernise maintenance, this process was hindered by the poor organisation of tasks. The MOP distributed roadworks between 19 public works districts, or 'Distritos de Obras Públicas'.[135] Until the late 1960s, these Distritos were not only in charge of carrying out maintenance, but also of supervising the work of private construction firms

[128] Uribe, 'La Mecanización de las Operaciones', Apéndice 38-46. See also the list of equipment used for different kinds of maintenance: paved roads, unpaved roads, works on surfaces and on verges: *Misión Técnica COMEC-HARRIS*, 160.
[129] This was part of the international debates around the mentality of machine operators. See AGN, AO, MOPT, Secretaría General, 202-32, Actividades de los Jefes de Grupos en los Distritos de Conservación (1970), 68.
[130] Uribe, 'La Mecanización de las Operaciones', 34.
[131] Uribe, 'La Mecanización de las Operaciones', 33-36.
[132] Uribe, 'La Mecanización de las Operaciones', 37.
[133] Uribe, 'La Mecanización de las Operaciones', 37.
[134] Uribe, 'La Mecanización de las Operaciones', 33.
[135] These were previously called 'Zonas de Carreteras'. See MOP, *Memoria de Obras Públicas 1945* (Bogotá, 1945).

and sometimes even of doing some construction themselves.[136] The MOP was not supposed to carry out construction work, but the Congress had the power to add roads that had been built by Departamentos or Municipios to the national network and since these roads had usually low technical standards, and were sometimes not even finished, the MOP often had to build or rebuild them before being able to start maintaining or paving them.[137] Given that the MOP did not have sufficient staff, the engineers overseeing maintenance and construction were often the same people.[138] Moreover, the length of roads for which each Distrito was responsible did not reflect its administrative capacity. The jurisdiction of the Distritos corresponded roughly to the political division of the country. This geographical division meant that the length of roads each Distrito had to maintain varied significantly. Some Distritos were responsible for more than 1,500 km of roads, while others oversaw the maintenance of less than 500 km – although most of them were in between these two figures.[139] This distribution of responsibilities disregarded not only the number of kilometres per Distrito but also, more importantly, whether each Distrito had the administrative capacity to manage its road length. Therefore, while some Distritos struggled to acquire enough resources, others were not taking full advantage of theirs.[140]

The way each Distrito was managed also caused difficulties and delays. Until 1969, each Distrito had the autonomy to choose its own institutional structure, and there was only one Distrito that had the official position of administrative manager.[141] There were no technicians or engineers in charge of organising and supervising maintenance operations, which meant that usually the person in charge of maintenance in the field was also responsible for coordinating the works at a larger scale.[142] Engineers usually delegated these tasks to foremen with little experience and limited knowledge of how to coordinate large-scale maintenance works, and in particular of how to acquire adequate materials and equipment.[143] Machinery and equipment were not controlled by each Distrito, but by the central offices of the

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[136] *Misión Técnica COMEC-HARRIS*, 2.
[137] This was a problem since the 1940s, when widening platforms, increasing curve radii, modifying alignments and building definitive works of art took about 70 per cent of the budget for paving in 1945. See MOP, *Memoria de Obras Públicas 1945,* XIV; MOP, Parsons, Brinckerhoff, Quade & Douglas, *Estudio del Transporte Nacional: Plan de Mejoramiento para los Transportes Nacionales* (Bogotá, 1962), I-31, I-35.
[138] AGN, AO, MOPT, División Ingeniería de Materiales, 51-15-209, Informes – Planos – Laboratorio Central – Ley 4 de 1966 – Decreto No. 248/66 (1962-1968), Letter from Reinaldo Perdomo, Jefe Rama Técnica to Alfredo D. Bateman, Director del Ministerio (1 July 1965).
[139] *Misión Técnica COMEC-HARRIS*, 141.
[140] *Misión Técnica COMEC-HARRIS*, 141.
[141] *Misión Técnica COMEC-HARRIS*, 12.
[142] *Misión Técnica COMEC-HARRIS*, 142.
[143] *Misión Técnica COMEC-HARRIS*, 143.

Equipment Division, which formed part of the Maintenance branch of the MOP. [144] However, machine maintenance and repair were not centralised; they were carried out in a central workshop in Bogotá and in smaller workshops in each Distrito as well. These processes were badly coordinated, and the lack of adequate inventories and norms to regulate maintenance and operation caused costly delays.[145] The organisation of the operators' work also wasted time and resources. The hasty construction of camps could often result in long commutes for workers and machinery.[146] Despite the increasing availability of trained operators, the Distritos were often short of money to cover the living costs of the operators whenever they needed to stay away from their homes.[147] In addition, every operator was hired to work with a particular kind of machine and, frequently, while a machine was being repaired its operator remained idle (while being paid a salary), even if he had the ability to use another type of machine.[148] The lack of an adequate and coordinated use of machines and tools, as well as of their timely and effective maintenance, led to great losses of machinery and equipment.

Indeed, despite the increasing number of machines, a significant proportion of them were in such bad condition that they could not be used. For instance, about half of the machines the MOP owned in 1958 were in poor or average condition and, ten years later, a third of the motor-graders were no longer usable, as well as almost half of the dumper trucks. [149] This was also the result of the use of poor quality materials, of the lack of adequate repairs and maintenance of the machines, and of the operation and storage of machines for more than ten years, i.e. well over their intended lifespan.[150] As a consequence, a great deal of manual maintenance was still taking place, even in the early 1970s. For instance, manual labour was used to clear vegetation from ditches.[151] However, given the large length of unpaved roads,

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[144] The Equipment Division was created in 1955 by the MOP and was in charge of determining machinery needs, controlling, regulating and directing the machines and their use, building and supplying workshops, programming machine repairs and training operators and mechanics. MOP, *Memoria de Obras Públicas 1958*, 43.

[145] *Misión Técnica COMEC-HARRIS* , 142. Often the lack of one machine or a small number of workers hindered progress considerably: 'pues en muchos casos, la falta de un solo equipo o de un pequeño número de obreros propicia que el avance de la obra se reduzca considerablemente con el consecuente incremento de costos', AGN, AO, MOPT, Secretaría General, 202-32, Actividades de los Jefes de Grupos en los Distritos de Conservación (1970), 19.

[146] AGN, AO, MOPT, Secretaría General, 202-32, Actividades de los Jefes de Grupos en los Distritos de Conservación (1970), 18.

[147] *Misión Técnica COMEC-HARRIS*, 143.

[148] It seems all operators were male. There were women working in construction camps but usually providing food, clothes, and medical attention. AGN, AO, MOPT, Secretaría General, 202-32, Actividades de los Jefes de Grupos en los Distritos de Conservación (1970), 51; *Misión Técnica COMEC-HARRIS*, 142.

[149] MOP, *Memoria de Obras Públicas 1958*, 44; *Misión Técnica COMEC-HARRIS*.

[150] *Misión Técnica COMEC-HARRIS*; Caro, 'Mantenimiento de Carreteras', 113.

[151] This was especially the case when machines could not reach. Caro, 'Mantenimiento de Carreteras', 111.

more motor-graders were needed, and while blades were attached to dumper trucks for the superficial levelling of unpaved roads, motor-graders were necessary for the deeper levelling that these roads required.[152] Therefore, in 1969 the MOP commissioned a study to determine how best to confront the continuous maintenance problems of the network. The consulting firms (Compañía Mexicana de Consultores en Ingeniería SA and Frederic Harris Engineering Corporation) concluded the MOP should buy 21 crawler tractors (costing 28,000 US dollars each), 38 rock crusher plants (at 90,000 US dollars each), 426 dumper trucks (for a total of 2.6 million USD) and 89 motor-graders (at 18,500 USD each), amongst other machines.[153] In total, it was estimated that the MOP needed to invest 21.4 million USD in machinery to respond in an appropriate manner to the maintenance demands. The study also recommended an administrative reorganisation to make the MOP more efficient. As a part of this new organisation, a list of the machines per number of kilometres of maintained road was suggested. In this list, dumper trucks still had a central role, as Annexe P illustrates.

In addition, the amount of paving the MOP carried out during these decades seems to have been excessive, according to the World Bank. Although the Bank was on board with paving a large proportion of the roads included in road projects in the early 1950s, by the late 1960s the Bank considered the Colombian Government was paving more than strictly necessary. In 1951, in the framework of the World Bank's first loan for road development, the Bank accepted to provide more funds to pave 50 per cent of the roads included in the project –and not 15 per cent as originally intended– at the request of the Colombian Government.[154] This was considered adequate given the rising transport demands and heavy rains. Nevertheless, in 1968, the Bank pointed out that the MOP had 'a tendency… to provide heavier and more elaborate pavements than absolutely necessary'.[155] This was attributed to the fact that the MOP was trying to compensate with paved surfaces the deficiencies of the drainage infrastructure.[156] However, this was not yielding good results and the World Bank suggested the use of more 'low cost paving methods, such as single and multiple surface treatments, which would probably be appropriate for many highways in Colombia'.[157] The slow adoption of these methods was probably related to the cost of finding adequate materials for this kind of soil treatment and stabilisation, as well as to the slow progress of the materials laboratories

152 Uribe, 'La Mecanización de las Operaciones', 32.
153 *Misión Técnica COMEC-HARRIS*.
154 IBRD, 'Appraisal of a Fourth Highway Project, Colombia' (Washington D.C., 1961), 2.
155 IBRD, 'Appraisal of Fifth Highway Project, Colombia' (Washington D.C., 1968), 11.
156 IBRD, 'Appraisal of the Sixth Highway Construction Project, Colombia' (Washington D.C.,1970), 10.
157 IBRD, 'Appraisal of Fifth Highway Project, Colombia' (Washington D.C., 1968), 11.

in the country; nonetheless, it seems that the MOP was spending unnecessary amounts on paving.

Furthermore, the definition of road maintenance was wide enough to include not only the physical condition and stability of the road, but also concerns about the information available to and the safety of the user. Maintenance works therefore included placing and maintaining traffic signs along the roads, as well as ensuring good road visibility.[158] In 1955, the first speed limit signs were placed in the country, 30,000 manuals about appropriate drivers' behaviour were distributed, and the first road markings were painted.[159] Road markings were painted with an imported machine and although in 1956 there were only five machines, in the same year there were already 474 km of roads with marked carriageways, and 673 km in the following year.[160] However, the advances on road safety and signage were slow, and the work of the road police is an example of this. The 'Unidad Vial' grew from having 20 men and no vehicles at its creation in 1955, to having 80 men and 25 vehicles in 1958.[161] The objective of this force was to prevent traffic infractions and accidents, respond and act as an intermediary when accidents did happen, offer mechanical support and guidance to drivers, and protect roads from damages inflicted by people, animals and machines.[162] The protection of the road included road maintenance activities as well, both routine and special (see Figure 5.3). In 1957, traffic infractions and road maintenance interventions were the second most frequent activities of the Unidad Vial, the first being offering mechanical support to vehicles on the roads.[163] Other infractions included driving without a license, overloading vehicles, driving to the left, herding cattle on the roads, cycling, and being aggressive towards the road police.[164] The MOP was also responsible for the health of its staff. The MOP had modern medical equipment in the major cities and ports, as well as mobile health units. Concerns about hygiene and access to food, medicines and other supplies in construction camps started in the mid-1940s.[165] By the late 1950s, although construction firms were meant to tend to the health of their workers and the hygienic conditions of their camps, the MOP also offered dentist services, equipment to test workers' blood and lungs, and an X-ray machine.[166] Thus,

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[158] AGN, AO, MOPT, Secretaría General, 202-32, Actividades de los Jefes de Grupos en los Distritos de Conservación (1970), 4.
[159] MOP, *Memoria de Obras Públicas 1958*, 28.
[160] MOP, *Memoria de Obras Públicas 1958*, 28.
[161] It seems no women were employed in this police unit, at least in this period. MOP, *Memoria de Obras Públicas 1958*, 27.
[162] MOP, *Memoria de Obras Públicas 1958*, 28.
[163] MOP, *Memoria de Obras Públicas 1958*, 28.
[164] MOP, *Realizaciones de Obras Públicas Nacionales*, 168.
[165] MOP, *Memoria de Obras Públicas 1945*, 24.
[166] Even though it is hard to judge how sufficient or effective these services were, it is possible to think that in a large developing country like Colombia these mobile health units were the first medical facilities

the MOP had a relatively comprehensive plan to improve working conditions and the experience of the road users. However, this objective was perhaps overambitious for the situation at the time, and might have ended up diverting scarce resources into less urgent activities, slowing down the modernisation of the road infrastructure.

Figure 5.3 The Unidad Vial learns how to operate a motor-grader, ca 1957

[Picture removed from ethesis version on copyright grounds]

Source: MOP, *Realizaciones de Obras Públicas Nacionales*, 171.

Finally, security issues also hindered the work of the MOP. Given the context of political violence in the country, attacks against transport infrastructure, camps, warehouses and other transport and communications works and facilities were common. The actions of subversive groups delayed some construction works.[167] In 1966, a decree established that any damage, destruction or interruption of these (or other related activities, such as petroleum exploitation)

to have ever reached certain rural communities. MOP, *Memoria de Obras Públicas 1958*; MOP, *Realizaciones de Obras Públicas Nacionales*, 313.

[167] For instance, for the construction of the Atlántico Railway in the 1950s, the National Army had to be present in every construction camp. Pachón, 'La Infraestructura de Transporte', 281. However, in these decades the actions of the guerrillas were highly localised and relatively weak militarily speaking; it was not until the 1980s that subversive activities truly affected road infrastructure in the mountains. Personal communication, Alexis de Greiff, September 2019.

was punishable by jail sentences of five to ten years.[168] This was a continuous problem during the period (and beyond), generating great human and material losses.[169]

Already in 1961, the World Bank had pointed out that the existing maintenance organisation was 'inadequate not only to protect the investment being made in new roads but also to conserve the existing network'.[170] Only in the mid- and late-1960s, however, with the advice of foreign consultants, a restructuration of the maintenance operations began. Therefore, by 1970, and despite the importance and efforts taken to modernise maintenance, the road network was still suffering from the interruption of the traffic. Despite poor conditions, roads managed, however, to support the heavy traffic of a nation that became dependent on its road network in the space of two decades.

Conclusion

In the 1950s and 1960s, road transport became the major land transport method in Colombia. The massive increase in heavy motor vehicles was only possible due to maintenance efforts and to the modernisation of improvement and maintenance operations. These processes were not part of a clear national policy, but rather a consequence of the state's failed railway and road construction endeavours. Maintaining roads passable for growing traffic was challenging not only because of the constraining traffic and environmental conditions, but also due to the low technical standards of the roads, which often made costly reconstruction works necessary. In view of these obstacles, the MOP had no choice but to mechanise and make the maintenance process more efficient, as well as to promote the adoption of modern engineering knowledge and techniques. Colombian engineers learned from not only Europe and the US, but also from other Latin American countries.

Nevertheless, the results of MOP's efforts were limited by its inability to coordinate maintenance, supervise construction, and provide clear technical road standards. Therefore, although the road network managed to respond to the transport demands, the condition of the network was never optimal but, in fact, highly deficient. This case shows how a developing nation struggled to respond to its urgent transport demands by multiplying its work fronts

[168] AGN, AO, MOPT, División Ingeniería de Materiales, 51-15-209, Informes – Planos – Laboratorio Central – Ley 4 de 1966 – Decreto No. 248/66 (1962-1968), 'Decreto 248 de 1966, Febrero 8'.
[169] Recently, after the peace treaty with the Fuerzas Armadas Revolucionarias de Colombia (FARC) guerrilla was signed, the FARC stated that, since their creation in 1964, they had built more than 3,000 km of roads. However, this is a topic that has not been yet studied.
[170] IBRD, IDA, 'Appraisal of a Fourth Highway Project, Colombia' (Washington D.C., 1961), 14.

without a clear plan of action, thus limiting its effectiveness. Maintenance was in this case an unintended way of keeping roads open to traffic, even if it was still weather dependent. Roads, perhaps better than railways, could allow traffic continuity and growth even given deficient conditions. This fact, in the context of funds scarcity and a poorly planned and executed transport policy, put them at a clear advantage.

Conclusion

This thesis is the first historical study of twentieth-century road construction and maintenance at a global scale. Roads are obviously a critical component of the expansion of transport in the twentieth century, though their development has been ignored, and often misunderstood. This thesis has highlighted for the first time the expansion and the modification that road networks experienced around the world from 1930 to 1970 – and especially the transformation of road construction and maintenance processes after the Second World War. This thesis showed that much road development, particularly in the developing world, did not revolve around passenger transport, but about around freight traffic. It has also showed the crucial importance of unpaved roads. Many roads, including those built in the 1930s, were built as what were called low-cost roads. Built down to a price, rather than up to a standard, the low-cost roads of the developing world, were designed to be improved over time – hence making maintenance and improvements essential to ensure future circulation. In fact, this thesis has shown that maintenance and upgradeability were the crucial factors that allowed low-cost roads to bear the rapidly growing heavy traffic of the post-1945 period.

It therefore represents a decisive shift away from the main themes of the existing historiography which focus on cars, motorways, tourism and leisure, and policy for road building. It also represents a notable shift in how we understand transport globally in the mid-twentieth century, by focusing on roads, rather than airplanes and railways.

Moving away from the main focus of the historiography on US road construction and its international influence (i.e. mostly traffic engineering and motorways), this thesis has pointed out for the first time that American road building and maintaining were the predominant model for the evolution of the standards, methods and equipment associated with low-cost construction. This significantly adds to our understanding of the influence of the US in the post-war period, as it held sway in British and French territories, where one might assume that this influence was less pronounced. Professional networks of engineers were crucial for the circulation and adaptation of this model across the world.

The case studies of Argentina, Colombia, Algerian Sahara and French West Africa all tell the story of roads acquiring a rising share of the transport of goods in places with both large and small railway networks, with different economic conditions, following industrialisation policies or depending on the export of raw materials, in colonial and independent contexts. Natural environments (not only climate and topography but also, in particular, soils and rocks) often made construction and maintenance expensive. However, what was truly challenging was the lack of knowledge about how to build motorable roads in these conditions, rather than the conditions themselves.

This thesis has made the case for studying the materiality of twentieth-century roads, as road length was but one of the factors that ensured the circulation of motor vehicles. In fact, this thesis showed that maintenance and improvement works were essential to allow the increased use of roads over time, as generally speaking the rate of traffic growth was faster than the pace of new road construction after 1945. Studying the physical properties of roads tells us not only about the changing load-bearing capacity of roads, but also about the emergence of new road construction and maintenance techniques and equipment that originated in the US, and quickly spread across the world in the post-war period.

*

This thesis has challenged the type of questions that have dominated the histories of twentieth-century roads, transport, and technology in several ways. First, by adopting a global perspective, this thesis has allowed us to appreciate the magnitude that road development acquired in this period, not only in Europe and the US, but also in Latin America, Asia and Africa. Although the cases of French West Africa, the Algerian Sahara, Argentina, and Colombia are explored in more detail, this thesis also examined in broad terms road engineering in the US and the French and British empires. This large-scale approach also made evident that, despite the diversity of social, political, and economic contexts, road construction and maintenance in developing countries and colonies shared significant features. Not only did these roads face similar challenges, the techniques and tools at the disposal of road engineers and workers were also alike, as they were the product of the adaptation of road-related knowledge and equipment that originated mostly in the US. Furthermore, the case studies also showed that acquiring experience in the national/colonial contexts was vital for the success of road construction and maintenance programmes. Twentieth-century roads were therefore not only factors of globalisation, but also the result of it, as their evolution cannot be understood without the consideration of these transnational exchanges and the varied yet homologous shapes that road-related knowledge and equipment took in every context.

Second, although focusing on roads, this thesis builds on recent studies that examine the relationship between various transport methods, and between roads and railways in particular. This thesis has demonstrated that roads competed with railways as main goods carriers in countries whose main routes were not all paved throughout and whose national networks were mostly unpaved. In Colombia and Argentina they did so despite the nationalisation of the railways. In fact, a transport policy that successfully coordinated roads and railways eluded these two countries during the period, as railway networks suffered from a constant decline of conditions and service, while roads absorbed a rising share of freight traffic – for which they were poorly prepared. The coordination between the two methods appears to have been less problematic in French West Africa, where the relatively small railway network and the centralisation of transport planning seem to have contributed to avoiding this problem. However, roads did carry higher volumes of freight than railways during the period.

In addition, this thesis added to the debate regarding the competitiveness of roads versus railways by suggesting that roads gained an advantageous position because they were more easily upgradeable, required a relatively low initial investment, and offered the possibility of allowing circulation even with low technical standards and poor maintenance conditions. Other factors were indeed important. The lobby of road-related industries and associations, the influence of politicians, local populations, and private firms, and the flexibility and savings that road transport offered (especially in contexts in which railway networks were highly fragmented) are all major phenomena that demand further research, and especially regarding the way they interacted with one another. Yet, those analyses should not forget the role that the material characteristics of low-cost roads played in these phenomena. In fact, it is significant that the provisional and suboptimal character of low-cost roads was not a deterrent to build them, but indeed part of the reason why they were built, even if it meant risking higher future expenditure. Similarly, although maintenance and upgrades were crucial for keeping roads open, the resources and efforts to perform these activities were often less readily available than those for new construction. Compared to railways, roads minimised public investment in the short- to medium-term and provided a quick, if makeshift, solution to transport demands.

Roads have not only attracted limited attention in comparison to other transport methods in the twentieth century, they have also until recently remained largely unproblematic categories in the histories of transport, mobility, and technology. Despite the fact that road use has been a common topic, lorries and other goods vehicles have remained marginal in most analyses. On a basic level, this thesis has called for the inclusion of freight given its significance for road development in particular, and for transport and globalisation history in general. Moreover, what happens *on* roads is deeply linked to their materiality. As some anthropologists have pointed out, paved and unpaved roads generate very different dynamics and acquire distinct meanings for both users and authorities.[1] This thesis did not focus on the impact of roads, but by studying roads' characteristics and how they came to be, my research has shed light on a number of issues that have so far attracted limited attention: the transformation and role of unpaved surfaces, the importance of road freight, and the study of how the knowledge to build and maintain roads was produced and moved around the world. The fact that British and French colonial engineers actively adopted and adapted American approaches in order to further the objectives of the colonial state, opens new avenues of inquiry for the histories of transport and technology, but also of empire, science, and development. Following the example of historians who have questioned the direction in which knowledge has usually been considered to circulate, this thesis also highlights the influence that the experience of French engineers in Africa exerted in the development of materials laboratories in France.

The conclusions reached by this thesis also hold other broad implications for histories of twentieth-century technology in the developing world. Moving beyond issues of local agency, taking materiality seriously allows us to understand the challenges, implications and consequences of road development. This approach also reveals that these phenomena were shaped by dynamic movements of people, money, knowledge and machines related to road development at different scales. These exchanges indeed reflect political and economic inequalities at different scales, but my research points to the need to take into account technical pragmatism and professional engineering networks in order to fully understand the way technical knowledge and instruments have moved around the world.

In addition, maintenance acquired a central role in this thesis, advancing recent initiatives that seek to study and underscore this often neglected aspect of technological development. The history of roads is a story of maintenance, which begins not after their use, but from their design itself. Beyond being a historiographical and methodological move, the centrality of maintenance seeks to reflect the importance that engineers accorded to it. In addition, the example of roads has illustrated how innovative maintenance can be, as road maintenance

[1] Penny Harvey and Hannah Knox, *Roads: An Anthropology of Infrastructure and Expertise* (Ithaca, New York, 2015); Fiona Wilson, 'Towards a Political Economy of Roads: Experiences from Peru', in *Development and Change*, 35 (2004), 525-546; Jeremy M. Campbell, 'Between the Material and the Figural Road: The Incompleteness of Colonial Geographies in Amazonia', in *Mobilities* (2012), 1-20. http://dx.doi.org/10.1080/17450101.2012.718429 (30/07/2019). See also Simón Uribe, *Frontier Road: Power, History, and the Everyday State in the Colombian Amazon* (Hoboken, New Jersey, 2017).

was often more about gradually creating something new, rather than about returning roads to their original state. Moreover, maintenance is also an instance of the importance of management experience. In fact, the successful mechanisation of maintenance was as much (or perhaps even more) a matter of distributing the work and planning the purchase of spare parts, as it was about importing heavy machinery. In other words, although maintenance was rarely prioritised and often disregarded, the limitations to its success came more from the *approach* to maintenance rather than from its absolute neglect.

This thesis also provided insights into the interactions between roads and the environment in a way that went beyond ecological damage and aesthetic concerns – the topics that have predominated in this type of analysis. The natural environment was an important influence on road development. Topography and climate often made works expensive and difficult, and the processes of adaptation of road engineering knowledge to local conditions were highly demanding. Funds limitations and the urgency of demands often meant that roads open to traffic were experimental, since controlled full-size experiments were concentrated in developed countries. Two conclusions stand out in relation to the type of challenge that the natural environment represented for road construction and maintenance. First, it was often the lack of knowledge about local environments (and in particular about how they would interact with road engineering approaches designed for different contexts), rather the environmental conditions themselves, that made construction and maintenance truly challenging. Second, many of the obstacles that could be identified as ‘natural’ were actually the result of human intervention in the first place. As the chapter on Colombia has explained, for example, problems related to heavy rains were not just caused by the tropical climate, but also by deficient drainage structures, poor maintenance, and by the erosion that originated in a lack of vegetation along the roads, among other factors.

Furthermore, this thesis builds on recent attempts to provide new accounts of the role that experts have played within development projects. Experimentation and make-do practices were an important part of road development in the developing world, where constraining environmental and financial conditions constituted powerful incentives. Engineers were conscious of the complexity of the conditions they faced, and constantly sought ways of adapting road engineering knowledge, methods, and equipment to local traffic and environmental contexts, as well as of creating new approaches and tools if necessary. The limited experience of engineers and construction firms in the late 1940s and early 1950s (and sometimes later) did result in the rapid failure of some roads, but this does not seem to have been caused by the neglect of local knowledge, but was rather related to management difficulties, the unprecedented and rapidly increasing traffic densities, the novelty of the task of building motorable roads (in the developing world, but also in general), as well as to low-cost construction. The adoption of palliative solutions was common to projects in both colonial and independent contexts. Exploring how pervasive this logic was is a topic that would benefit from further research, but it is clear that the model of *Seeing like a State* does not apply to roads or road engineers.[2]

*

Taking a global perspective has come largely at the expense of the detailed analysis of specific road projects or secondary and tertiary networks. Further work concentrating, for instance, on a particular road and its transformation over time would likely produce valuable insights into the adaptation and innovation of engineers' activities to changing demands and evolving tools and techniques. The ancient Great Trunk Road (stretching from Calcutta in Eastern India to Kabul in today's Afghanistan) could be a good case for such study, as it continues to be used today, and its evolution in the twentieth century tells a story that combines concrete and unpaved surfaces, lorries and bullock carts, as well as modern steel bridges and ancient resting facilities for travellers. Moreover, even though traffic surveys are rare for this period, a smaller geographical scope would probably facilitate the juxtaposition of traffic data with that of the type of surface provided on different stretches of roads. Adopting a reduced scale could also make possible an oral history approach, which would no doubt deepen our understandings of the life trajectories and daily tasks of engineers, foremen, machine operators, and other workers (especially in places where road engineering publications are less common or detailed).

While this thesis has sketched out the importance of mechanisation, due to space and time constraints it has not dealt substantively with the evolution of road-building machinery and other related equipment – including materials laboratories' instruments. There is abundant material available to further our knowledge on these objects, which have played major parts in the construction of the twentieth-century world. The archives of the RRL in London, for example, are a rich source of material on the evolution of soil studies in Africa and South East Asia, as well as on the increasing use of aerial photography and methods to interpret the resulting images. The history of the emergence and evolution of this type of facilities in the developing world would likely also tell us a great deal about the patterns of exchange and marginalisation that have characterised the spread of technical knowledge around the world.

[2] Scott, *Seeing like a State*.

Further research on the production, adaptation, and use of such transformative objects and organisations is needed to better understand how modern infrastructure came to be, as well as the implications of such changes.

Similarly, even though this thesis has pointed out the significance of lorries for road development (and that of animal-drawn vehicles in some contexts), it has not addressed the evolution of lorries and other types of goods vehicles. Although the use of commercial vehicles in Sub-Saharan Africa (and in some cases their substantial modification) has attracted some attention, many questions remain unanswered about the vehicles that have had the most effect on roads worldwide. What (if anything) was distinctive about the design of goods vehicles as compared to automobiles in this period? The way in which goods vehicles moved around the world can also provide insights into the priorities and conditions of every context. Based on my research and the current historiography on automobiles we can infer that the use of a particular goods vehicle depended most likely not only on the production or import of a particular model, but also on the costs they incurred (in terms of purchase, operation, maintenance) – and thus also on the size and acquisitive power of trucking firms – on the type of goods to be transported, as well as on road design characteristics, amongst others.

Finally, this thesis has hinted at the important role of the private sector in road development in both independent and colonial contexts and has made evident a number of potential lines of inquiry that expand the type of private actors that have previously been studied. Beyond the actions of the road lobby, the work and staff of large international construction and consulting firms merit careful consideration, as well as that of those with a smaller range. There are abundant resources to conduct such studies. The World Bank archives (both at its headquarters and online), for instance, offer a great deal of material on the projects they financed all over the world, and on the relationship the Bank had with the borrower governments. In addition, while this thesis has touched upon the role of the World Bank and the FIDES, many other funding agencies had significant roles in road development, and more can be done to understand the methods and impact of their work. The way in which cost-benefit studies evolved over time is, for example, a major topic that deserves more attention. The analysis of the crucial part played by the private sector can also be useful to further reflecting on the differences between communist/socialist and capitalist countries. Although the Eastern Bloc did experience some road development during the period, it remained mostly reliant on railways. The shift experienced in some countries from railways to roads has been more asserted than questioned, as has the predominance of railways in the Eastern Bloc. Now that the world is witnessing a revival of the railway, reflecting on these issues seems all the more timely and valuable.

Annexes

Annexe A. Road networks in selected countries and colonies in 1930, 1951, 1967 and 1970

	1930	1951			1967			1970		
	Road length (km)	Road length (km)	Length of road per sq. km	Length of roads per 100,000 populatio n	Road length (km)	Percent age paved	Density of total network in km per sq. km	Road length (km)	Percent age paved	Density of total network in km per sq. km
Algeria	35,007	65,200	0,03	741	-	-	-	75,953	-	0,03
Argentina	212,625	416,800 (d)	0,14	2,589	215,30 4 (g)	12,3	0,07	201,05 9	16,1	0,07
Austria	42,000 (a)	28,500 (e)	0,34	413	92,975 (i)	100	1,11	-	-	-
Belgium	30,407	62,700 (e)	2,05	712	91,718	81,4	3,00	92,021	81,4	3,00
Bolivia	5,768	14,300 (d)	0,01	376	24,286	2,5	0,02	-	-	-
Brazil	121,500	275,200	0,03	523	826,42 5 (g)	3,82	0,09	939,61 5	4,51	0,10
Chile	40,000	52,300	0,07	902	54,394	12,9	0,72	70,549	11,0	0,093
Colombia	30,997 (a)	19,600	0,01	156	39,857	10	0,03	43,838	10	0,04
France	651,832 (a)	830,000 (e)	1,5	1,976	780,30 9 (h)	100 (j)	1,42	788,75 3 (h)	100 (j)	1,42
French West Africa	46,000 (a)	50,000 (m)	0,01	547 (n)	-	-	-	-	-	-
Ghana (Gold Coast)	-	14,600	0,06	324	32,187 (g)	11,9	0,13	32,187	12,9	0,13
Great Britain	288,218	295,800	1,3	583	326,11 0	100	1,42	334,13 3	100	1,45
India (British India)	456,260 (a)	432,800 (e)	0,14	121	884,15 9	33,9	0,27	963,01 7	34,7	0,29
Indonesia (Dutch East Indies)	58,218	70,300	0,03	90	84,268	25,0	0,04	84,292	25	0,04
Iraq	7,725	19,300	0,06	402	17,480	-	0,04	18,605	26	0,04
Italy	316,347 (a)	195,000 (e)	0,64	415	282,00 1	90	1	284,98 8	92	0,95

Ivory Coast	-	-	-	-	35,684	3,0	0,11	34,961	3,6	0,10
Japan	943,965	943,431 (b)	-	-	996,820	9,01	2,70	1,014,593	14,95	2,74
Kenya	-	32,700 (e)	0,05	606	41,939	5,3	0,07	42,764	7,2	0,07
West Malaysia (British Malaya)	-	10,100 (f)	0,07	194	16,312	81,9	0,12	17,456	84,8	0,133
Mexico	226,700	130,500	0,06	508	65,164	58,5	0,03	71,520	60	0,036
Morocco	6,298	48,400 (e)	0,12	569	23,975	82,7	0,05	24,775	85,0	0,056
Nigeria	-	45,100	0,04	180	88,904	17,2	0,09	88,904	17,2	0,096
Pakistan	-	114,600	0,12	152	42,174	48	0,44 (l)	36,116		0,39 (l)
Spain	87,089 (c)	221,000	0,45	773	138,669 (g)	60,1	0,27	139,394	67,1	0,28
Tunisia	11,454	14,400	0,08	411	17,110	50	0,104	17,856	51	0,109
Uganda	-	13,700	0,05	269	24,173	26,4 (k)	0,12	-	-	-
USSR	1,149,999	-	-	-	-	-	-	-	-	-
US	4,867,019	5,325,300 (e)	0,68	3,494	5,962,631	41	0,64	6,003,007	43,6	0,64

(a) Figure from 1929

(b) Figure from 1956

(c) Figure from 1926

(d) Figure from 1948

(e) Figure includes urban roads

(f) Does not include roads on rubber estates or mines, which form an important part of the network

(g) Figure from 1968

(h) Excluding 698,000 km of rural roads

(i) Excludes private roads (33,500 km of paved roads and 64,000 km of unpaved private roads)

(j) Includes only national roads (as opposed to departmental/regional and local)

(k) All unpaved roads are classified as 'all weather'

(l) Taking into account about 200,000 km of 'fair weather' earth roads

(m) Estimation from R. Lantenois, Director-General of Public Works in French West Africa at the time. Including tracks the network length was about 90,000 km

(n) Including tracks

\- No data

Sources: Comisión Económica Para América Latina (CEPAL), *Boletín Estadístico de América Latina*, Vol. VI, No. 2 (New York, 1969), 135-137; IBRD, IDA, 'Appraisal of a First Highway Project, Ghana' (Washington D.C., 29 June 1973), 6; IBRD, IDA, 'Proposal for a Highway Engineering Credit, Ghana' (Washington D.C., 9 June 1969), 2; International Chamber of Commerce, *A Statistical Survey of World Highway Transport* (Paris, 1931), 18-23; International Road Federation, *World Road Statistics, Revised Second Edition* (London, 1953), 11-14; International Road Federation, *World Road Statistics, 1967-1971* (London, 1972), 10-26; Statistics Bureau, Ministry of Internal Affairs and Communications, Japan, Historical Statistics, Chapter 12 Transport, Table 12-4 Length of roads and paved roads (CY 1894—1935, FY 1936—2004) Available at http://www.stat.go.jp/english/data/chouki/12.html (06/06/2019); Lantenois, 'Section 1, Road Construction and Maintenance, Question II, Progress made since the Congress at The Hague in 1938 in the study of road subgrades, French West Africa', in *Permanent International Association of Road Congresses* (Lisbon, 1951), 2.

Annexe B. Main railway network lengths in selected countries and colonies in 1930 and 1965 (miles)

	1930	**1965**
Algeria	2,992	2,548
Argentina	23,825	27,169
Australia	26,554	24,933
Austria	4,453	4,094
Belgium	3,157	2,760
Brazil	20,180	20,806
Bulgaria	1,834	2,383
Cameroon	313	330
Canada	42,075	43,355
Chile	5,549	4,857
China (excluding Manchuria)	11,807	19,500
Czechoslovakia	8,027	8,313
Denmark	3,332	2,476
Finland	3,186	3,570
France	26,222	23,729
Great Britain	20,445	15,319
Germany (East and West for 1965)	36,250	31,254
Greece	1,682	1,616
Hungary	4,785	5,036
India	41,724	36,210
Indonesia	4,135	3,788
Iran	261	2,174
Iraq	752	1,026
Ireland	2,668	1,455
Italy	10,427	10,313
Japan	9,057	12,886
Lebanon	136	208
Luxembourg	332	210

Madagascar	432	537
Malawi	129	316
Malaysia	1,013	1,124
Mexico	14,789	14,179
Morocco	556	1,110
New Zealand	3,295	3,263
Nigeria	1,758	1,989
Norway	2,407	2,702
Pakistan	6,370	7,039
Paraguay	309	309
Peru	2,613	1,509
Portugal	2,124	2,238
Rhodesia	2,328	2,655
Romania	6,964	6,838
South Africa	13,469	13,621
Spain	7,343	8,296
Sweden	10,268	8,347
Switzerland	3,247	3,168
Syria	483	526
Tunisia	1,281	1,488
Turkey	3,264	4,907
United States (excluding Alaska)	249,052	212,059
USSR	48,381	80,321
Total	698,035	690,859
Total excluding USSR	649,654	610,538

Note: The names of countries and colonies have been kept as in the original source. This table includes only the countries for which the yearbook had information on both years. The figures exclude light railways, steam tramways and interurban electric lines. The original source warned that the figures are not strictly comparable due to the difficulty of adjusting earlier mileages to political boundaries at the time, and to the divergence in practices as to what constituted minor railways, light railways and secondary lines.

Source: *Directory of Railway Officials & Year Book 1966-1967* (London, 1967), 572-74.

Annexe C. Estimated number of vehicles in circulation in selected countries and colonies in 1930, 1952, 1967 and 1970 (in thousands) – Part 1/2

	1930				1952					
	A	B	C	D	A	B	C	D	E	F
Algeria	36.7	6.3	2	45	50	36		86	9.77	1.31
Argentina	321.9	80.2	2.6	404.7	221.1	128.3	11.9	361.3	22.44	0.86
Belgian Congo	-	-	-	-	12	14.8	0.2	27	-	-
Belgium	90	46.5	1	137.5	304	164.7	3	471.7	53.6	7.52
Bolivia	1.7	0.9	0.1	2.7	4	8.5	0.5	13	3.42	0.9
Brazil	90	64.5	38.1	192.6	262.5	210.4	16	488.9	9.29	1.77
Chile	19.3	8.6	4.9	32.8	38	30.9	4.4	73.3	12.64	1.4
Colombia	10	6	-	16	40.5	34.1	8.9	83.5	6.63	4.26
France	930.1	366		1290.1	1381.8	883.9	24	2289.7	54.52	2.75
French West Africa	2.6	4.1	0.08	6.7	12.9	26.7	0.6	40.2	2.44	0.44
Ghana (Gold Coast)	-	-	-	-	7.1	10.7		17.8	3.96	1.21
Great Britain	980.8	329.7	97.9	1408.4	2380.3	934	135.8	3450.1	68.05	11.66
India (British India)	87.4	27	27.7	142.1	150	89.8	30.2	270	0.76	0.62
Indonesia (Dutch East Indies)	37.7	11.4	31.5	80.6	36	24.6	8.4	69	0.88	0.98
Iraq	3.1	1.2	0.1	4.4	11	9.2		20.2	4.21	1.04
Italy	157.4	52.5	31.6	241.5	425.6	237	13	675.6	14.37	3.46
Ivory Coast										
Japan	4.1	26.2	51.2	81.5	-	-	-	556 (h)	-	-
Kenya	-	-	-	-	19.2	16.3		35.5	6.57	1.08
Madagascar	2	0.7	-	2.7	5	6.8	0.2	12	-	-
Malayan Union and Singapore (*)	-	-	-	-	53.3	21.4	1.9	76.6	14.73	7.58
Mexico	35.7	14.8	21.7	72.2	193.1	127	18.8	338.9	13.19	2.59

Morocco	17	6.8		23.8	42	28.7	0.3	71	8.35	1.46
Nigeria	-	-	-	-	12.2	14.1		26.3	1.05	0.58
Pakistan	-	-	-	-	28.8	8.9	11.6	49.3	5.38	4.01
Spain	127.8	48.5		176.3	95	84	8	187	6.54	0.84
Tanganyika	-	-	-	-	-	6.2	7.7	13.9	-	-
Tunisia	11.7	1.5	0.5	13.7	19.2	9.6	0.6	29.4	8.4	2.04
Uganda	-	-	-	-	0.7	0.4	1.1	2.2	1.98	0.73
USA	23121.5	3379.5		26501	42570.5	8721.1	134	51425.6	337.44	9.65
USSR	10	11.5	2.5	24	-	-	-	-	-	-

Annexe C. Estimated number of vehicles in circulation in selected countries and colonies in 1930, 1952, 1967 and 1970 (in thousands) – Part 2/2

	1967						**1970**					
	A	**G**	**C**	**D**	**E**	**F**	**A**	**G**	**C**	**D**	**E**	**F**
Algeria	106.18	67.48		173.66	-	-	135.17	77.33		236.11 (a)	-	-
Argentina	1138.63	629.17	25.24	1793.04	12.4	-	1550	750	33.4	2333.4	-	-
Belgian Congo												
Belgium	1667	262.06 (a)	9.2	1938.32	202	21,1	2033.93	212.15	16.16	2301.5	233	-
Bolivia	26	17.4	2	45.4	11.9	-	11.1	28.3	2.22	52.77	-	-
Brazil	1337	415.2	40.3	1792.5	20.92	-	2695	599	59	3353	36.9	-
Chile	170.04	51.51	11.28	232.84	26	4.3	177.02	134.9	15.95	327.88	29	4.6
Colombia	100.73	143.78	22.06	266.57	12.87	-	105.4	188.34	32.63	326.37	12.6	6.8
France	10565	1756	43	12,405 (a)	250	16	12470	1810	35	14,370 (a)	281	18.1
French West Africa												
Ghana (Gold Coast)	-	-	-	-	-	-	28	16.8		56	-	-
Great Britain	10318.3 (b)	1618.1	78.7	12,021.1 (a)	225	36.8	11540.3	1616.4	77.8	13,239.5 (a)	244	39.6

India (British India)	477.25	264.8	74.31	888.80 (f)	1.62	0.87	588.83	318.91	91.28	1,092.33 (f)	1.85	0.82
Indonesia (Dutch East Indies)	184.95	94.89 (a)	18.84	298.68 (a)	2.67	3.52	235.81	99.81 (a)	23.45	359.08 (a)	3.02	4.32
Iraq	60.66	30.05	9.1	99.81	11.6	5.6	67.42	32.73	9.24	109.39	11.6	5.9
Italy	7294.56	703.96	34.47	8,041.70 (a)	149	28	10200	914	33	11,277 (a)	206	39
Ivory Coast	43.49	26.33	0.96	73.31 (a)	16.3	2	55	29.1	2	89.1 (a)	18.1	2.5
Japan	3836.41	6531.83	129.21	10,501.09 (a, g)	104.72	10.53	8778.97	8850.43	187.98	17,825.77 (a, g)	171.54	17.56
Kenya	47.97	42.25 (a)	2.05	92.27 (a)	9.3	2.2	58.45	52.73 (a)	2.65	113.84 (a)	10.9	2.9
Madagascar	39.75	25.87	2.02	69.60 (a)	9.7	1.8	-	-	-	-	-	-
Malayan Union and Singapore (*)	182.44	46.5	4.23	233.18	26.9	14.3	238.36	55.82	5.93	312.37 (a)	-	-
Mexico	812.4	408.5	27.5	1248.4	27.32		1242.84	581.81		1824.65	-	23.7
Morocco	178.38	63.78	3.45	248.56 (a)	17.4	10.2	222.46	83.44 (a)		304.25 (a)	19.6	12.3
Nigeria	69.49	31.37		101.48 (a)	1.65	1.13	-	-	-	-	-	-
Pakistan	77.56 (i)	28.58 (i)	12.31 (i)	124.37 (a) (i)	1.07 (i)	0.49 (i)	93.45 (i)	32.51 (i)	13.39 (i)	145.88 (a) (i)	1.22 (i)	0.59 (i)
Spain	1334.83	524.44	25.18	1884.45	56.5	14.1	2377.72	710.22	30.72	3118.66	91.6	22.3
Tanganyika												
Tunisia	56.6	30.86	1.48	88.94	19.1	5.2	66.43	35.27	1.97	103.68	20.4	5.8
Uganda	29.16	8.82	0.88	39.62 (a)	4.9	1.6	-	-	-	-	-	-
USA	80414.18	15416.77	337.92	96,944.87 (a)	487.2	16.3	89279.86	18748.42	379.02	109,304.76 (a)	529.4	18.1
USSR	-	-	-	-	-	-	-	-	-	-	-	-

A – Automobiles

B – Commercial Vehicles (i.e. load-carrying motor vehicles such as lorries, ambulances, fire engines and vehicles employed in Government or Municipal services excluding buses and coaches)

C – Buses and coaches

D – Total

E – Number of vehicles per 1,000 persons

F – Number of vehicles per km of road

G – Goods vehicles

- No data

(a) Figure includes non-agricultural tractors

(b) Figure includes taxis and estate cars.

(c) Figure from 1971

(d) Including light commercial vehicles

(e) Excluding public service vehicles, mini-buses and jeeps,

(f) Including trailers, ambulances and other special vehicles

(g) Includes three-wheeled vehicles

(h) Number of registered vehicles

(i) Figures as of 30th of June

(*) West Malaysia for 1967 and 1970

Sources: Comisión Económica Para América Latina (CEPAL), *Boletín Estadístico de América Latina*, Vol. VI, No. 2 (New York, 1969), 136; IBRD, IDA, 'Appraisal of a First Highway Project, Ghana' (Washington D.C., 29 June 1973), 6; IBRD, 'Staff Appraisal Report, Highway Maintenance Project, Bolivia' (Washington D.C., 18 May 1978), Table 2.3 'Motor Vehicle Fleet 1967-1974'; International Chamber of Commerce, *A Statistical Survey of World Highway Transport* (Paris, 1931), 12-17; International Road Federation, *World Road Statistics, Revised Second Edition* (London, 1953), 15-18, 118-20; International Road Federation, *World Road Statistics, 1967-1971* (London, 1972), 27-36, 51-76; Statistics Bureau, Ministry of Internal Affairs and Communications, Japan, Historical Statistics, Chapter 12 Transport, Table 12-10 'Motor Vehicles Owned by Kind', Available at http://www.stat.go.jp/english/data/chouki/12.html (06/06/2019); the Grupo Executivo de Integração da Política de Transportes (GEIPOT) in 1970 quoted in IBRD, IDA, 'Appraisal of a Third Construction Project, Brazil' (Washington D.C., 29 February 1972), Table 9 'Vehicle Fleet'; Álvaro Pachón and Maria Teresa Ramírez, *La Infraestructura de Transporte En Colombia Durante El Siglo XX: Una Descripción Desde El Punto de Vista Económico* (Bogotá, 2006), Anexo II.40.

Annexe D. Map of Trans-Saharan projects before independence

[Picture removed from ethesis version on copyright grounds]

Source: Taken from the website of the Sahel and West Africa Club Secretariat (SWAC/OECD, 2014). Based on *Les collections de l'histoire* n. 58-63; *Encyclopédie d'outre-mer*, 1956. Available at http://www.oecd.org/swac/maps/maps-atlasofthesahara-sahel.htm (31/08/2019)

Annexe E. Map of roads in French West Africa, big arteries of colonial and inter-colonial circulation, ca. 1951

[Picture removed from ethesis version on copyright grounds]

Source: ANOM 3TP/141, Plans d'équipement, 1938-1951 (Afrique Occidentale Française: routes), Sécrétariat d'État aux colonies, Inspection Générale des Travaux Publics. *L'équipement économique des colonies françaises, Afrique Occidentale Française – les routes,* s.d.

Annexe F. Roads and tracks lengths in French West Africa per territory, 1956 (km)

Territories	Total of roads (a)	Total of tracks	Total
Senegal	8,658	3,000	11,650
Sudan	6,162	5,000	11,150
Mauritania	2,675	1,000	3,700
Guiney	5,092	2,500	7,600
Ivory Coast	8,752	8,000	16,750
Dahomey	3,972	1,200	6,200
Niger	3,504	5,000	8,504
Upper Volta	8,361	8,100	16,450
Total French West Africa	47,176	33,800	80,976

(a) General network and roads of local interest

Source: ANOM 3TP/78, Afrique Occidentale Française, 1953-1957, République Française, *Afrique Occidentale Française*, *Sommaire Conditions Économiques*, 1956, 30.

Annexe G. Annual and permanent maintenance units and the type of work each machine performed, French West Africa, 1955

Annual maintenance unit, French West Africa, 1955

Annual Maintenance		
Type of work	**Machine**	**Number of machines**
Re-shaping ditches and verges	Motor-grader	2
Re-shaping profile		
Spreading improving course		
Digging borrow-pits	Bulldozer	1
Road-widening		
Cleaning verges		
Loading, transport and arranging imported materials	Lorry	2+ Depending on distance from materials source
Compacting improving course	Pneumatically-tyred roller	1
Transport of water	Road-tanker	2+ Depending on distance from water source

Source: J. Chauchoy and R. Lantenois, 'Section 1: Construction and Maintenance, Question 3, Low Cost Roads, French West Africa', in *Permanent International Association of Road Congresses* (Istanbul, 1955), 25-26.

Permanent maintenance unit, French West Africa, 1955

Permanent Maintenance		
Type of work	**Machine**	**Number of machines**
Patching Transport of material for patching	Lorry	2+

Re-shaping after rainy season	Motor-grader	1
Elimination of corrugations	Planing machine	1
	Trains of tyres	
	Light motor-grader	
Compaction of new surface	Regular motor traffic	-

Source: J. Chauchoy and R. Lantenois, 'Section 1: Construction and Maintenance, Question 3, Low Cost Roads, French West Africa', in *Permanent International Association of Road Congresses* (Istanbul, 1955), 25-26.

<u>Annexe H. The evolution of Argentina's real GDP per capita and monthly inflation rate, 1946-1984</u>

[Picture removed from ethesis version on copyright grounds]

Source: Taken from Guido di Tella and Rudiger Dornbusch (eds.), *The Political Economy of Argentina, 1946-83* (London, 1989), 3.

Annexe I. Map of national road network per type of surface, Argentina, 1961

[Picture removed from ethesis version on copyright grounds]

Note: in red, paved roads; in blue, ‘consolidado’ (improved, or ‘compacted’); in green ‘natural’ (unimproved, or dirt); in yellow, track.

Source: República Argentina, Ministry of Public Works and Services, Transportation Planning Group, *A Long Range Transportation Plan* (Buenos Aires, 1962), Appendix 2 Highways.

Annexe J. Map of national road network per type of surface, Argentina, 1970

[Picture removed from ethesis version on copyright grounds]

Note: in red, paved roads; in blue, ‘consolidado’ or improved; in green ‘natural’, or unimproved; in yellow, track; in dashed red, in process of being paved; in dashed blue, in process of being improved; blue crosses, not opened yet; in red and blue, stabilised with asphalt.

Source: Dirección Nacional de Vialidad, *Panorama Vial de la República Argentina. Situación Actual de la Dirección Nacional de Vialidad* (Buenos Aires, 1970), 24.

Annexe K. Map of average road traffic per day in some selected national roads in Argentina, 1960

[Picture removed from ethesis version on copyright grounds]

Source: República Argentina, Ministry of Public Works and Services, Transportation Planning Group, *A Long Range Transportation Plan* (Buenos Aires, 1962), Appendix 2 Highways.

<u>Annexe L. The evolution of Argentina's national road network according to type of surface, 1940-1969 (percentage)</u>

[Picture removed from ethesis version on copyright grounds]

Note: in black, paved; blue, improved; green, 'natural' (i.e. unimproved earth); and yellow, tracks.

Source: Dirección Nacional de Vialidad, *Panorama Vial de la República Argentina. Situación Actual de la Dirección Nacional de Vialidad* (Buenos Aires, 1970), 27.

Annexe M. Map of transport infrastructure in Colombia, 1950

[Picture removed from ethesis version on copyright grounds]

Source: Adapted from Álvaro Pachón and Maria Teresa Ramírez, *La Infraestructura de Transporte En Colombia Durante El Siglo XX: Una Descripción Desde El Punto de Vista Económico* (Bogotá, 2006), Mapa II-1.

Annexe N. Map of national roads according to the period in which they were finished, Colombia

[Picture removed from ethesis version on copyright grounds]

Source: Adapted from Álvaro Pachón and Maria Teresa Ramírez, *La Infraestructura de Transporte En Colombia Durante El Siglo XX: Una Descripción Desde El Punto de Vista Económico* (Bogotá, 2006), Mapa II-9.

Annexe O. Total road network in Colombia according to classification, 1950-1970 (km)

	National			Deptal.	Municipal	Particular	Total Network
Year	**Paved**	**Unpaved**	**Total**				
1950	100	12,100	12,200	-	-	-	-
1951	176	12,324	12,500	-	-	-	-
1952	239	12,768	13,007	6,619	574	592	20,792
1953	452	13,446	13,898	7,504	681	1,397	23,480
1954	563	13,335	13,898	8,362	1,035	1,451	24,746
1955	661	13,711	14,372	8,444	2,118	1,668	25,941
1956	861	13,312	14,173	10,197	2,353	1,888	28,611
1957	1,160	12,775	13,935	10,927	2,240	2,101	29,203
1958	2,220	11,529	13,749	11,595	2,399	2,276	30,019
1959	2,223	12,844	15,067	12,857	2,528	2,388	32,840
1960	2,619	13,258	15,877	14,694	2,758	3,561	36,890
1961	2,784	13,597	16,381	14,716	2,647	3,723	37,467
1962	2,841	13,671	16,512	15,925	2,627	2,784	37,848
1963	3,191	13,501	16,692	16,859	2,610	2,925	39,086
1964	3,217	13,523	16,740	-	-	-	-
1965	3,497	13,982	17,479	17,931	4,584	3,367	43,361
1966	3,572	13,954	17,526	-	4,821	3,389	-
1967	3,853	14,144	17,997	-	1,966	3,024	-
1968	4,235	14,607	18,842	-	2,081	3,011	-
1969	4,499	14,768	19,267	-	-	-	-
1970	4,821	15,094	19,915	-	1,664	3,821	-

- No data

Source: Álvaro Pachón and Maria Teresa Ramírez, *La Infraestructura de Transporte En Colombia Durante El Siglo XX: Una Descripción Desde El Punto de Vista Económico* (Bogotá, 2006) Anexo II.37.

Annexe P. List of machinery needed for routine maintenance according to road surface in Colombia, 1969

From 1969, every Distrito was divided in 'Seccionales', of 360 km of roads each. The following lists correspond to the ideal plant for each Seccional depending on whether the roads were paved or not.

Ideal plant for the routine maintenance of 360 km of paved roads:

Nº	Machine	Work
6	Dumper Truck (3 ½ Yd3)	Transporting gangs and carrying equipment to clean the road.
4	Dumper truck (5 Yd3)	Carrying materials for re-levelling and patching. This equipment is only recommended when it is not possible to hire a particular to carry materials.
2	Motor grader	Mixing asphalt for re-levelling, patching and shaping of lateral areas.
1	Loader (frontal on wheels)	
2	Tractor with bulldozer (D4)	Shaping lateral areas, exploitation of materials, landslides, etc.
2	Tandem roller (6-9 ton)	
1	Tanker	Irrigating asphalt.
2	Tanker with heater	Transporting asphalt.
3	Gear pump 3"	For asphalt.
3	Lorry with 500 l tank for asphalt (Camión-patrulla con tanque de asfalto de 500 litros, con calentador e irrigador de mano)	
1	Lawn mower	
1	Agricultural tractor for the lawn mower	

Ideal plant for the routine maintenance of 360 km of unpaved roads:

Nº	Machine	Work

6	Dumper Truck (3 ½ Yd3)	Transporting gangs and carrying equipment to clean the road.
6	Dumper truck (5 Yd3)	Carrying materials for re-levelling and patching. This equipment is only recommended when it is not possible to hire a particular to carry materials.
4	Motor grader	Shaping surface.
2	Front loader (on wheels, 2 Yd3)	
1	Front loader (on tracks, 2 Yd3)	
1	Tanker	Irrigating water.
4	Motor pump	For water for the tankers.
1	Lawn mower	
1	Agricultural tractor for the lawn mower	

Source: AGN, AO, MOPT, Secretaría General, 166-27, Compañía Mexicana de Consultores en Ingeniería SA (COMEC) and Frederic Harris Engineering Corporation, *Misión Técnica COMEC-HARRIS, Información al Señor Ministro Acerca de las Necesidades de Equipo para la Conservación de Carreteras a Cargo del Ministerio* (Bogotá, 1969), 162-164.

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